mar. Invert

PROCEEDINGS

AND

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

VOL. XXVIII.

SESSION 1913-1914.

LIVERPOOL:
C. TINLING & Co., LTD., PRINTERS, 53, VICTORIA STREET.

1914.

CONTENTS.

I.—Proceedings.

II.—Transactions.

PROCEEDINGS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY

OFFICE-BEARERS AND COUNCIL.

Ex-Presidents:

1886—1887 Prof. W. MITCHELL BANKS, M.D., F.R.C.S.
1887—1888 J. J. DRYSDALE, M.D.
1888—1889 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1889—1890 Prof. W. A. HERDMAN, D.Sc., F.R.S.E.
1890—1891 T. J. MOORE, C.M.Z.S.
1891—1892 T. J. MOORE, C.M.Z.S.
1892—1893 ALFRED O. WALKER, J.P., F.L.S.
1893—1894 JOHN NEWTON, M.R.C.S.
1894—1895 Prof. F. GOTCH, M.A., F.R.S.
1895—1896 Prof. R. J. HARVEY GIBSON, M.A.
1896—1897 HENRY O. FORBES, LL.D., F.Z.S.
1897—1898 ISAAC C. THOMPSON, F.L.S., F.R.M.S.
1898—1899 Prof. C. S. SHERRINGTON, M.D., F.R.S.
1899—1900 J. WIGLESWORTH, M.D., F.R.C.P.
1900—1901 Prof. PATERSON, M.D., M.R.C.S.
1901—1902 HENRY C. BEASLEY.
1902—1903 R. CATON, M.D., F.R.C.P.
1903—1904 Rev. T. S. LEA, M.A.
1904—1905 ALFRED LEICESTER.
1905—1906 JOSEPH LOMAS, F.G.S.
1906—1907 Prof. W. A. HERDMAN, D.Sc., F.R.S.
1907—1908 W. T. HAYDON, F.L.S.
1908—1909 Prof. B. MOORE, M.A., D.Sc.
1909—1910 R. NEWSTEAD, M.Sc., F.E.S.
1910—1911 Prof. R. NEWSTEAD, M.Sc., F.R.S.
1911—1912 J. H. O'CONNELL, L.R.C.P.
1912—1913 JAMES JOHNSTONE, D.Sc.

SESSION XXVIII., 1913-1914.

President:

C. J. MACALISTER, M.D., F.R.C.P.

Vice-Presidents:

Prof. W. A. HERDMAN, D.Sc., F.R.S.
JAMES JOHNSTONE, D.Sc.

Hon. Treasurer:

W. J. HALLS.

Hon. Librarian:

MAY ALLEN, B.A.

Hon. Secretary:

JOSEPH A. CLUBB, D.Sc.

Council:

HENRY C. BEASLEY.
G. ELLISON.
H. B. FANTHAM, D.Sc., B.A.
W. P. GOWLAND, D.Sc.
W. T. HAYDON, F.L.S.
S. HENDERSON, M.D.
DOUGLAS LAURIE, M.A.
Prof. B. MOORE, M.A., D.Sc.
Prof. R. NEWSTEAD, F.R.S.
J. H. O'CONNELL, L.R.C.P.
MAY RATHBONE, (Miss).
WM. RIDDELL, M.A.

Representative of Students' Section ;

Miss DUVALL, B.Sc.

REPORT of the COUNCIL.

During the Session 1913-14 there have been seven ordinary meetings and one field meeting of the Society.

The communications made to the Society at the ordinary meetings have been representative of almost all branches of Biology, and the various exhibitions and demonstrations thereon have been of great interest.

By invitation of the Council, Prof. R. A. S. Macalister, M.A., F.S.A., of University College, Dublin, lectured before the Society, at the March Meeting, on "Clanmacnois, a University of Early Christian Ireland."

The Library continues to make satisfactory progress, and additional important exchanges have been arranged.

The Treasurer's statement and balance-sheet are appended.

The members at present on the roll are as follows :—

Ordinary members	52
Associate members	8
Student members, including Students' Section, about	30
Total	90

SUMMARY of PROCEEDINGS at the MEETINGS.

The first meeting of the twenty-eighth session was held at the University, on Friday, October 10th, 1913.

The President-elect (C. J. Macalister, M.D., F.R.C.P.) took the chair in the Zoology Theatre.

1. The Report of the Council on the Session 1912-1913 (see "Proceedings," Vol. XXVII, p. viii.) was submitted and adopted.

2. The Treasurer's Balance Sheet for the Session 1912-1913 (see "Proceedings," Vol. XXVII, p. xvii) was submitted and approved.

3. The following Office-bearers and Council for the ensuing Session were elected :—Vice-Presidents, Prof. Herdman, D.Sc., F.R.S., and James Johnstone, D.Sc. ; Hon. Treasurer, W. J. Halls ; Hon. Librarian, May Allen, B.A. ; Hon. Secretary, Joseph A. Clubb, D.Sc. ; Council, H. C. Beasley, G. Ellison, H. B. Fantham, D.Sc., B.A., W. P. Gowland, D.Sc., W. T. Haydon, F.L.S., S. Henderson, M.D., Douglas Laurie, M.A., Prof. B. Moore, M.A., D.Sc., J. H. O'Connell, L.R.C.P., Prof. Newstead, M.Sc., F.R.S., May Rathbone (Miss), W. Riddell, M.A.

4. Dr. C. J. Macalister, F.R.C.P., delivered the Presidential Address on "Some relationships between Education and Co-ordination of Function" (see "Transactions," p. 3). A vote of thanks was carried with acclamation.

The second meeting of the twenty-eighth session was held at the University, on Friday, November 14th, 1913. The President in the chair.

1. Prof. Herdman submitted the Annual Report on the work of the Liverpool Marine Biology Committee and the Port Erin Biological Station, and included an interesting account of a biological cruise off the West Coast of Scotland (see " Transactions," p. 23).

The third meeting of the twenty-eighth session was held at the University, on Friday, December 12th, 1913. The Vice-President (Dr. Johnstone) in the chair.

1. Mr. J. Erik Hamilton read a paper on the Whaling Station at Blackrod Bay, West of Ireland, with a description of the species of Whales brought to the station.

The fourth meeting of the twenty-eighth session was held at the University, on Friday, January 23rd, 1914.

This was a joint meeting with the Students' Society.

Miss Duval (President Students' Society) in the chair.

1. Prof. Moore lectured on " Photosynthesis " to a large and appreciative audience.

The fifth meeting of the twenty-eighth session was held at the University, on Friday, February 13th, 1914. The President in the chair.

1. Mr. Riddell, M.A., communicated the Annual Report of the Investigations carried on during 1913 in connection with the Lancashire Sea Fisheries Committee (see " Transactions," p. 91).
2. Dr. Alfred Holt submitted a paper on " The Purple Pigment obtained from certain Marine Organisms," an account of analytical research on the Gastropod *Purpura lapillus* and the Ascidian Diazona.

The sixth meeting of the twenty-eighth session was held at the University, on Friday, March 13th, 1914. The President in the chair.

1. Prof. R. A. S. Macalister, M.A., F.S.A., of University College, Dublin, lectured before the Society on the invitation of the Council, on "Clanmacnois, a University of Early Christian Ireland." On the motion of Prof. Bosanquet, seconded by Dr. Caton, a vote of thanks was accorded to the lecturer.

The seventh meeting of the twenty-eighth session was held at the University, on Friday, May 8th, 1914. The President in the chair.

1. The L.M.B.C. Memoir on "The Echinoderm Larvae of Port Erin," by H. C. Chadwick, A.L.S., was submitted.
2. Prof. Herdman gave a description of newly discovered Antiquities from the Isle of Man.

The eighth meeting of the twenty-eighth session was the Annual Field Meeting held at Heswall, on Saturday, June 12th. The Society inspected the Royal Liverpool County Hospital for Children, on the invitation and under the guidance of Dr. Macalister. Demonstrations were given from actual patients of the very satisfactory results obtained, and the visit was of great interest. At the short business meeting held after tea, on the motion of the President from the chair, Prof. J. W. W. Stephens, M.D., D.P.H., was unanimously elected President for the ensuing session.

LIST of MEMBERS of the LIVERPOOL BIOLOGICAL SOCIETY.

SESSION 1913-1914.

A. Ordinary Members.

(Life Members are marked with an asterisk.)

ELECTED.

1908 Abram, Prof. J. Hill, 74, Rodney Street, Liverpool.

1909 *Allen, May, B.A., Hon. Librarian, University, Liverpool.

1888 Beasley, Henry C., Prince Alfred Road, Wavertree.

1913 Beattie, Prof. J. M., M.A., M.D., The University, Liverpool.

1903 Booth, jun., Chas., 30, James Street, Liverpool.

1912 Burfield, S. T., B.A., Zoology Department, University, Liverpool.

1886 Caton, R., M.D., F.R.C.P., 78, Rodney Street.

1886 Clubb, J. A., D.Sc., Hon. Secretary, Free Public Museums, Liverpool.

1910 Ellison, George, 52, Serpentine Road, Wallasey.

1910 Fantham, H. B., D.Sc., B.A., School of Tropical Medicine, University, Liverpool.

1902 Glynn, Dr. Ernest, 67, Rodney Street.

1913 Gowland, Dr., Anatomy Department, University, Liverpool.

1886 Halls, W. J., Hon. Treasurer, 35, Lord Street.

1910 Hamilton, Mrs. J., 96, Huskisson Street, Liverpool.

1896 Haydon, W. T., F.L.S., 55, Grey Road, Walton.

1912 Henderson, Dr. Savile, 48, Rodney Street, Liverpool.

1886 Herdman, Prof. W. A., D.Sc., F.R.S., Vice-President, University, Liverpool.

1893 Herdman, Mrs. W. A., Croxteth Lodge, Ullet Road, Liverpool.

1912 Hobhouse, J. R., 54, Ullet Road, Liverpool.

1902 Holt, A., Dowsefield, Allerton.

1903 Holt, George, Grove House, Knutsford.

1903 Holt, Richard D., M.P., 1, India Buildings, Liverpool.

1912 Jackson, H. G., M.Sc., Zoology Department, University, Liverpool.

1898 Johnstone, James, D.Sc., Vice-President, University, Liverpool.

1894 Lea, Rev. T. S., D.D., The Vicarage, St. Austell, Cornwall.

1896 Laverock, W. S., M.A., B.Sc., Free Public Museums, Liverpool.

1906 Laurie, R. Douglas, M.A., University, Liverpool.

1912 Lyon (Miss), Una, High School for Girls, Aigburth Vale, Liverpool.

1912 Macalister, C. J., M.D., F.R.C.P., President, 35, Rodney Street, Liverpool.

1905 Moore, Prof. B., University, Liverpool.

1913 Mottram, V. H., Physiological Department, University, Liverpool.

1904 Newstead, Prof. R., M.Sc., F.R.S., University, Liverpool.

1904 O'Connell, Dr. J. H., 38, Heathfield Road, Liverpool.

1913 Pallis, Mark, Tätoi, Aigburth Drive, Liverpool.

1903 Petrie, Sir Charles, 7, Devonshire Road, Liverpool.

1903 Rathbone, H. R., Oakwood, Aigburth.

1890 *Rathbone, Miss May, Backwood, Neston.

1910 Riddell, Wm., M.A., Zoology Department, University, Liverpool.

1897 Robinson, H. C., Malay States.

1908 Rock, W. H., 25, Lord Street, Liverpool.

1894 Scott, Andrew, A.L.S., Piel, Barrow-in-Furness.
1908 Share-Jones, John, F.R.C.V.S., University, Liverpool.
1895 Sherrington, Prof., M.D., F.R.S., University, Liverpool.
1886 Smith, Andrew T., 21, Croxteth Road, Liverpool.
1903 Stapledon, W. C., "Annery," Caldy, West Kirby.
1913 Stephens, Prof. J. W. W., M.D., The University, Liverpool.
1903 Thomas, Dr. Thelwall, 84, Rodney Street, Liverpool.
1905 Thompson, Edwin, 25, Sefton Drive, Liverpool.
1889 Thornely, Miss L. R., Nunclose, Grassendale.
1888 Toll, J. M., 49, Newsham Drive, Liverpool.
1913 Waring, Miss, Bedford College, Bedford Street, Liverpool.
1891 Wiglesworth, J., M.D., F.R.C.P., Springfield House, Winscombe, Somerset.

B. Associate Members.

1905 Carstairs, Miss, 39, Lilley Road, Fairfield.
1913 Hamilton, Erik, B.Sc., 96, Huskisson Street, Liverpool.
1905 Harrison, Oulton, Denehurst, Victoria Park, Wavertree.
1910 Kelley, Miss A. M., 10, Percy Street, Liverpool.
1912 Parkin, Miss A. B., 3, Cairns Street, Liverpool.
1913 Smith, Miss L. M., 39, Parkfield Road, Liverpool.
1903 Tattersall, W., D.Sc., The Museum, Manchester.
1910 Tozer, Miss E. N., Physiology Laboratory, University, Liverpool.

C. University Students' Section.

President : Miss Duvall, B.Sc.

Secretary : Miss Clarke.

Treasurer : Mr. Daniel.

(Contains about 30 members.)

D. Honorary Members.

S.A.S., Albert I., Prince de Monaco, 10, Avenue du brocadéro, Paris.

Bornet, Dr. Edouard, Quai de la Tournelle 27, Paris.

Claus, Prof. Carl, University, Vienna.

Fritsch, Prof. Anton, Museum, Prague, Bohemia.

Haeckel, Prof. Dr. E., University, Jena.

Hanitsch, R., Ph.D., Raffles Museum, Singapore.

Solms-Laubach, Prof.-Dr., Botan. Instit., Strassburg.

THE LIVERPOOL BIOLOGICAL SOCIETY.

Dr. IN ACCOUNT WITH W. J. HALLS, HON. TREASURER. Cr.

1913, Oct. 1st, to Sept. 30th, 1914.	£	s.	d.	1913, Oct. 1st, to Sept. 30th, 1914.	£	s.	d.
To Teas and Attendance at Meetings	3	2	0	By Balance from last Account	3	0	0
,, Messrs. Tinling & Co.	40	0	0	,, Subscriptions	28	7	0
,, Hon. Secretary's Expenses	2	8	6	,, Associate Members	2	2	0
,, Hon. Librarian's Expenses	5	9	0	,, Student Members	0	10	0
,, Stationery	0	5	2	,, Student Society	0	10	0
,, Subscription returned	0	5	0	,, Subscriptions in Arrear	11	11	0
,, Balance	6	2	11	,, Subscriptions in Advance	2	2	0
				,, Sale of Volumes	9	1	6
				,, Bank Interest	0	9	1
	£57	12	7		£57	12	7

Audited and found correct,

HENRY C. BEASLEY.

LIVERPOOL, *October 26th, 1914.*

TRANSACTIONS

OF THE

LIVERPOOL BIOLOGICAL SOCIETY.

INAUGURAL ADDRESS

ON

SOME RELATIONSHIPS BETWEEN EDUCATION AND CO-ORDINATION OF FUNCTION.

By CHARLES J. MACALISTER, M.D., F.R.C.P.,
President.

[Delivered October 10th, 1913.]

Ladies and Gentlemen.—In the days when Professor Herdman and I worked together in the practical laboratories of the University of Edinburgh we used to regard Biology and Natural History as being practically synonymous terms, and in the classes we dealt rather with the morphological, histological and physiological characteristics of a series of types of animals and plants than with problems of life itself.

Now Biology has a very different significance. The word may be said to represent a hub round which there are grouped many branches of work, for there is not a single point connected either with the structure or constitution, or with the functions of living matter or of living beings, which does not involve considerations which come into the category of the biological sciences.

Not only, therefore, must we include among biologists the zoologist and botanist, the physiologist and the bio-chemist, but also workers in every region of knowledge which can throw light upon matters appertaining to life; among these regions comes medicine with its special branches and its allied sciences, and the physician, endeavouring to explain deviations from the normal and to rectify these deviations on rational therapeutic lines, may, I venture to think, fairly claim a place in the brotherhood. I presume that it is a recognition of this claim which has prompted you, not for the first time, to invite a

member of that profession to occupy the presidential chair of your Society during the session which we are now inaugurating, and this is an honour which, I assure you, I greatly appreciate, and for which you have my sincere thanks.

It may at first sight appear somewhat strange to choose anything which has to do with education for the subject of my address this evening, but if we bring to mind the fact that knowledge can only be conceived of in association with life and in relation to the living apparatus or being which contains it or is capable of containing it, I think you will agree that there are some biological points connected with education which may be worthy of consideration.

Knowledge and ignorance, although abstract subjects which are not measurable, have yet the peculiarity that they have a kind of quantitative relationship to one another; for instance, a totally untaught being which is quite ignorant has that ignorance lessened and its place taken by knowledge when it learns something. Ignorance, therefore, like knowledge, has its relationships with life, and we have perhaps as much reason to speak of the amount of ignorance possessed by a living creature as we have to estimate the amount of its knowledge.

By the living creature I do not necessarily mean a human creature. A tree or a plant is just as much alive as a man is, but according to the present state of our wisdom it possesses a vast amount of ignorance and it has no capability of acquiring knowledge.

When we consider other forms of life, such as the bee or ant, or the bird or fish, or the dog, we recognise that each has some kind or kinds of knowledge, and as we climb up the scale we are driven to the conclusion that every class of animal has knowledge within certain limitations, depending upon the state of development of its apparatus for knowing, which is generally proportionate to its requirements.

When we come to the human being it is abundantly evident

that every kind of the genus "Homo" has not the same capacity for education, and even among members of the same families of men there are great variations so far as these possibilities are concerned. Manifestly then, as in the case of the lower classes of animals, human beings present varying capacities of understanding, so that, as the old students of metaphysic would have put it, we may say that there is knowledge of which some individuals are incapable and it is possible that there is knowledge of which most, if not all, may be incapable.

Knowledge, then, is an attribute of life, and in the case of the human being we have the very highest organisation for its inception, storage and utilisation; but that organisation is subject to variations in its qualities, and I want to try and suggest how these qualities may be modified through varying influences, and how education, in its restricted or scholastic sense, not only advances the possession of intellectual and physical acquirements, but also when properly employed may have a therapeutic value.

When a child is born, the functions which mainly concern it are those which have to do with its nutrition. It feeds, it sleeps, and it has lusty powers of signalling with its lungs and voice when its tissues, having burnt up the supply of fuel, demand more. It has little, if any intelligence, and no knowledge beyond the instinctive. It immediately proceeds to grow at a great pace, and before many weeks have passed some signs of intelligence begin to show. Its ignorance becomes replaced by a very little knowledge which is gained through its senses; in fact, its education has commenced, and as time goes on its development and growth and knowledge increase in relation to one another, until at last, when the period of childhood comes and with it the further development of the higher faculties, education takes place rapidly through the channels of every sense and the hitherto ignorant centres become invaded by a

great variety of knowledge and impressions. This invasion progresses with such rapidity that almost every child is regarded by its parents and those about it as being precocious, simply because they observe how quickly the understanding, the powers of attention and at last those of speaking, of memorising and of reading and writing, in fact all the powers of reception and of representation, become acquired. The child's chatter, its imagination and faculty for romance are all the outcome of its rapidly developing intelligence, through the medium of which knowledge becomes distributed to the various centres whose functions come to be unified and co-ordinated, and to work harmoniously together.

This co-relation of function is so essential for the effectiveness of education that I trust you will pardon me for saying a few words concerning it, by way of emphasising its importance, even although I reiterate some old and well-known facts. Many of the diseases of the invalid child which interfere with its education involve an upsetting of the balance of the normal co-relations of function, and we can learn a great deal about co-ordination by observing these effects of its disorders. The quality of a child's intelligence often appears to become depreciated when it is suffering from a chronic disease, and we frequently note how greatly it improves when the disease itself is attended to. The education of the child and of its cerebral centres is under these circumstances interfered with, not necessarily because its intelligence or capacity for knowing is actually deficient, but through the mental or nervous deviation which is brought about by the disease from which it may be suffering, and the releasing of this energy no doubt leads to a restoration of the nervous balance and enables the intelligence to resume its normal distributive functions, the intelligence being essential for the proper teaching of some of the various centres which co-operate one with another. We all know that people with low types of intelligence are only fitted for the lower

types of work—they have less fineness of movement and of touch, and are only capable of the coarser employments. Their powers of co-ordination are inferior because the centres are less taught. There are many conditions of disease and of abnormality which throw light upon the inter-relationship which exists between the intelligence and the proper activity of some of the cerebral centres, indicating that these may remain inco-ordinate simply because they have not been taught to functionate. Take, for instance, some of those varieties of mental deficiency in young children whose motor centres may be quite developed and potentially active, but they are unable to use them. They cannot walk, often they cannot hold their heads up, and they cannot talk, not because they are unable to move their limbs—they do this in an aimless kind of way, and they utter incoherent sounds. Muscularly they may be very strong. All the sensory channels of education may be open, but their lack of intelligence or of capacity for knowing has rendered them unable to learn to use their centres and to make the movements effective, with the result that there is movement without co-ordination.

Illustrative case shown :—

H. W.—Aged 4. Appeared to be a perfectly bright child until about eighteen months old, when he had an attack of meningitis. Ever since then his intelligence centres have been deficient. He understands what is said to him, and will sometimes perform actions of response. He is very strong in the arms and legs, kicks about vigorously, but is absolutely without power of co-ordination. Show him a toy, he laughs at it and makes aimless movements with his hands, but has no power of co-ordination to take hold of it.

We have another striking example of the fact that individual centres require to be taught to functionate, in the case of the deaf-mute, whose perfectly-developed centres for speech remain inactive because the sense of hearing, through which they normally become educated, is absent. Deaf-mutes have often plenty of intelligence, but never having heard, they are practically ignorant of the existence of sound, and they will explain to you that they cannot imagine what sound is like

So far as their brains are concerned they have all the potentialities for speech and hearing, but the centres connected with these functions remain inert, merely because untaught. They do not often attain to the same standard of education as normal people, because one of the principal channels of education is entirely cut off, and all the knowledge which they acquire comes through the visual and other remaining sense-organs. Their intelligence, however, enables them to bring other centres not usually employed for the purposes of inter-communication and of expressing ideas, abstract and concrete, into a condition of co-ordination, and without any necessary scholastic teaching they automatically learn to communicate with each other and with the outside world by means of that wonderful language of signs through which the lights and shades of speech are alone possible to them and such poetry as they possess is given expression to. This co-opted language of signs, though not taught in the schools, is handed down from generation to generation of the deaf and dumb and is practically universal, being understood by them all the world over. We had a striking example of this fact some years ago when an Armenian missionary gave an address to the deaf and dumb in this city. He could speak no English and his Armenian thoughts were entirely expressed in signs. The deaf members of his audience closely followed all that he had to say, and the address was spoken in English by an interpreter of the signs who, of course, had no knowledge of the Armenian tongue. This universality of the sign language was recognised by a Scotch schoolmaster in Oxford, called Dalgarno, in the early part of the 17th century (1626-87), and he wrote a book in 1664, entitled " Ars Signorum, Vulgo Character Universalis," suggesting that it might be employed as a universal language for the hearing as well as for the deaf.

We do not know whether the speech and hearing centres of the deaf-mute fail to develop thoroughly because they are

unused; it would seem likely, but we do know that if the sense of hearing is restored, even after many years, they are capable of being educated. There are not many instances recorded where people, either born deaf or becoming so at an early age, have regained their powers of hearing, but such as there are have been instructive in so much that they serve to demonstrate that a long period elapses between the time of recovery and the possibility of differentiating sounds and of using spoken language. One of these histories is related in the well-known story of the son of Croesus, who was a deaf-mute, and his father, as a rich man surely would do, sought every means for his relief. Among other measures he consulted the Oracle at Delphi; the Pythian, however, advised him to let things alone and warned him that on the day that the boy spoke misfortune would come to the kingdom, and the warning seems to have been fulfilled, for when the fortifications of Sardis were taken, a Persian, not knowing Croesus, was about to slay him, and he, not caring to survive his misfortunes, would have met the stroke of death, but his hitherto speechless son, moved with fear and agony, cried out, "Man, kill not Croesus." These were his first words, and from that time forward he continued to speak. It is presumed that the boy must have recovered his hearing and have understood language for some time previous to this event and that he spoke for the first time under the influence of strong emotion.

In 1703 the son of a tradesman of Chartres, who had been deaf and dumb up to his twenty-fourth year, heard for the first time on the occasion of the ringing of the bells of the town one cloudy day, this being the prevalent custom to dispel a storm. Sounds were a great mystery to him for a long time, but in the course of several months he came to understand language and eventually became able to speak himself.

Another similar kind of case was that of one David Fraser who was born deaf and remained mute till his seventeenth year,

when he quite suddenly recovered his sense of hearing. He was very alarmed when he first heard sound, but as in the former case his centres for hearing and speech subsequently became educated. As in all of these cases he became able to understand language long before he was capable of using it, this corresponding with what is well recognised to be the case in the healthy child. Long before a normal baby can put together a few words, it has a considerable understanding of what is said to it. It may, indeed, have a good deal of knowledge concerning language, but remains ignorant concerning the co-related ability to use it, and we have that curious coincidence of knowledge and ignorance; a physiological inco-ordination, which is a prototype of many forms of functional disturbances which are capable of being righted by suitable educational measures. The instances which I have quoted serve to exemplify how anything which causes an alteration in the intelligence or in the capacity for knowing, may upset the balance of function, and I again want to refer to the fact that this capacity is apt to become lessened by the diversion of nervous energy by diseased conditions in parts other than the brain. A patient who has a crippling disorder often becomes hipped and to a certain extent introspective as a result of it, and there is no doubt that an educational appeal to his intelligence may have a hastening effect upon the recovery from the disease.

Speaking of physiological inco-ordination reminds one that there is in most people a normal want of balance, insomuch that the two sides of the body seldom possess the same amount of strength or fineness of function—most of us being right-handed. There is a strong side and a weak side, and this does not apply only to physical strength and dexterity, for it has a bearing upon vitality and upon susceptibility to deformity and disease. Most deformities, such as club-foot and other malformations are on the left side, and so are a large number of acquired diseases such as those of the lungs. For instance,

I have at the present moment at the Royal Country Hospital for Children, at Heswall, half a dozen cases of an infective disease of the lungs giving rise to its fibrosis and contraction, and in every one of them the left lung is alone involved.

It is difficult to explain this greater vitality and strength of the right side. Some say it is due to its having a more direct blood supply—others that it is a purely hereditary matter, owing to the greater use of the right arm through long generations The fortunate thing is that there is uniformity in the difference, otherwise it would lead to a great deal of inconvenience in the way of using tools, and in education in the technical arts.

I have said that the blood supply to the right limbs is more direct than it is to the left, but it has to be remembered that the supply to the right side of the brain is also more direct than it is to the left side, which rather annuls that theory. Whatever may be the explanation, it is an interesting fact which may possibly have a bearing upon certain abnormalities of co-ordination. By way of illustrating this, I show you a left-handed boy who has a very bad stammer, and one speculates as to whether this marked inco-ordination may be related in some way to the left-sided cerebral speech centres being unbalanced through the stronger right-sided development in the brain. You will observe how, when this boy speaks, there are jerking movements of the right arm and leg indicating an upset of other motor centres besides those of speech.

Illustrative case shown :—

W. M.—Example of bad stammering in a left-handed boy. Note how his right side twitches when he speaks, indicating a complete want of co-ordinated control, as though his energy expended in overcoming the want of balance all comes from the left motor centres. Speculate whether stammering in right-handed people may not be due to some altered co-ordinative relationships between the two sides of the brain. This is probably due to a structural defect and is quite often hereditary.

Left-handedness varies greatly in degree. Of the boys at Grafton Street Industrial School about 6 per cent. are affected, some pronouncedly so, others being merely ambidextrous.

The impression that a difference in nutrition has something to do with the matter is favoured by there being often a noticeable hemi-atrophia on the weaker (right) side, and the hair on the limbs and chest is sometimes rather more abundant or more marked on the left than on the right.

Among deaf-mute children we get no stammering that I am aware of, but quite a number of them (about $7\frac{1}{2}$ per cent. in the School for the Deaf and Dumb) are left-handed and spell and sign with the left hand on the right instead of the right hand on the left as is usually the case. These are all taught to write with the right hand and they do this excellently, but occasionally they have a peculiar type of ambidexterity, and are known as mirror-writers, because they can write with the left hand from right to left, and will read such writing as quickly and accurately as you and I can do it in the ordinary way. They are called mirror-writers because to read their left-handed writing we require to hold the paper or slate before a looking glass.

These children seem to be able to see things the wrong way round without being educated to do so, and they illustrate another form of unusual bilateral co-ordination. [Several deaf and dumb "mirror-writer" children shown to illustrate this condition.]

There are some other cases which we meet with in the hospitals which throw light on the way in which normal bilateral co-ordination is maintained. It is well known, for instance, that when the eyes are moved from side to side, or in any given direction the relationship of their axes to one another remains the same, excepting in cases of general enfeeblement in children, when the eyes may act to a certain extent independently of one another. But suppose that something happens to weaken one of the ocular muscles, say the right external rectus, so that when the patient is asked to look to the right there is difficulty or inability to turn the eye in that direction. Ask

him to follow your finger with his eyes from left to right and it will be noted that the eyes will remain in the same axes until the point is reached when the weakened muscle fails to contract, then, as the finger travels to the right, the left eye will overshoot the mark and look beyond the finger. This is due to the fact that under usual circumstances there is an equal distribution of energy sent into the co-ordinating muscles of the two eyes, but whenever the point is reached where the weakened muscle would come into action there is an immediate though unconscious access of energy distributed to both eyes, ineffective so far as the faulty one is concerned, but causing its fellow to receive so much that it travels too far. We see the same kind of thing occasionally in cases of long-continued muscular spasm which causes distortion of a foot. After the surgeon has corrected the deformities, either by tendon or muscle transplantation, or by simple shortening or lengthening, the effort to use the newly-corrected limb sometimes causes a temporary spasmodic deformity in its fellow, owing to an excess of energy reaching the corresponding muscle. In both of these cases education generally leads to recovery of function. In the case of the squinting eye, the altered axes at first give rise to double vision and other symptoms, which disappear as parts of the retina not accustomed to act in concert learn to do so. In the case of the limb, a transplanted muscle learns to take on a function for which it was not originally intended and concerted action becomes re-established; were it not so, many of the operations of this type for correction of deformity would be unavailing. There is no difficulty in finding a variety of other well-known types of disorder to illustrate the point that conditions which promote the diversion of an unusual amount of nerve energy in some given direction cause an upset in the co-ordinative balance. We see it in some of the so-called habit spasms. I saw a boy some years ago who was a source of great anxiety to his people, and one of great interest to the inhabitants

of the little town in which he resided, on account of his habit of dancing along the street. Instead of walking normally, he progressed with a skipping action, varied every dozen paces or so by a complete rotation. There were constant twitchings of his face and one shoulder and he had become stupid intellectually. All of these were inco-ordinate conditions and were traced to eye strain. He had been a great reader, and the trouble immediately ceased on paralysing his accommodation with atropine and so relieving the abnormal distribution of his nervous energy.

Hitherto I have spoken, in a somewhat general way, of the dependence of the centres upon an integrity of the channels through which knowledge is usually taken in, and upon the quality of the intelligence or capability of knowing, for their education. There is another element, however, which has to be appreciated, and without which absolute morphological or anatomical perfection is unavailing. I refer to the chemical side of the question, which is of the greatest importance in relation to the health of every function in life.

Life itself consists of an innumerable series of chemical reactions which are constantly taking place; we may say in broad terms that practically every function of which the organs are capable, depends upon some form of chemical change for its healthy performance. The physiologist or bio-chemist no longer contents himself by making observations regarding the microscopic characters of cells and their nuclei—he regards structure only in relationship to function, the chemistry of the cell contents, and of the fluids which surround the cells, being matters which largely concern him. The work which has already been accomplished in this direction has shown that the chemical reactions in the cell are very numerous, and so constant withal that bio-chemistry is practically being brought within the realms of the exact sciences. I have no intention of entering into any of these cytological problems—indeed my

knowledge of them is very limited, but from a physician's point of view the recognition that health depends upon a perfect co-ordination of the chemical processes in the cells of which the various organs are composed is one of the greatest moment. In the old days it was known that certain drugs, given even in minute quantities, produced wonderful therapeutic results, and they were called sedatives, or stimulants, or alteratives, or some other name indicating, not the true pharmacological action, but their clinical effects. Now, the inter-relationship which exists between the plant and the animal is placing a new complexion upon some forms of therapeutic actions which are known to be in the direction of restoring the chemical inco-ordinations which express themselves in disease. The same principle holds good in the administration of the internal secretions and of extracts of organs of various kinds, which contain some of the chemical substances necessary for healthy metabolism.

In childhood these metabolic changes are very active. The tissues are growing, organs are developing, the intelligence and all the functions of cerebration are advancing, and the amount of chemical change going on in the body must be enormous. In addition to the general daily routine of metabolism, if one may so speak of it, there are periodical or cyclical or climacteric periods, all of which involve a change of chemistry to meet the requirements of the developing organs, and we can hardly feel surprised that in this period of life many of the diseases are related to cellular instability, due to faults in chemistry—in other words there is inco-ordination of chemical function. Many of the neuroses and psychoses of childhood are related to this kind of change, and symptomatically they express themselves in some of those diseases of inco-ordination, such as the climacteric chorea, so common at puberty, and which often has mental symptoms attached to it. Want of brightness in school children is frequently due to these chemical disorders, and by giving attention to their metabolic wants, it is possible some-

times to brighten them up and prevent the necessity for their being sent to special schools. Backwardness has to be sharply distinguished from idiocy or mental defect; the one is due to chemical faults, the other very generally is related to altered structure. Children are more or less like plants, insomuch that if the soil in which their cells grow is unsuited for them, or if it contains anything which tends to damage them, stunted growth, stunted intellect and stunted function result, and stupidity in school should lead to a careful enquiry as to its cause, which, if a nutritive or chemical one, can often be dealt with and rectified. Simple backwardness often dates from a very early period of the child's life. It means slowness of development, so that the child is to be regarded as being really considerably younger than its years, and consequently it is in every respect below standard. It is commoner among children of the poor and among the neglected than among the better to do, and consequently in industrial schools we see a good deal of it. It accounts, for instance, for some of the large number of cases of incontinence of urine and kindred troubles, which are so common in these schools, conditions which are not infrequently speedily cured by attending to the child's faulty chemistry.

I need not go into details regarding the clinical features of these backward cases—how they do not learn to speak perhaps until their fifth or sixth year, how the intestinal functions remain infantile, how the lengths of the limbs remain like those of younger children and so forth, but by way of emphasising the general slowness of the nervous system which is apt to characterise them, I show you two little girls, each aged four years. One of them is normal so far as her nerves and mental condition are concerned; she is bright, alert, every muscular movement sharp and her arms and legs normal in length. She is active and hardly still for a moment, her energies always seeking an outlet in some kind of movement or another. The other is a backward child; she is passive in character and

slow in her movements. If you place her arms or legs or head in any position you please, she will allow them to remain so almost indefinitely, so that she is like a little lay figure. When she came to us at Heswall three months ago she could not speak, and she was more like a child of eighteen months than one of four years of age. Like so many of these cases, she has developed rapidly and has grown much under the influence of thyroid gland substance, and now she is beginning to talk and to play and to take an interest in her surroundings and toys, but as you see, her muscular slowness or stupidity still remains. Experience teaches us, however, that this will clear up and that she will in time become a normal child.

Illustrative case shown :—

F. H.—Aged 7. About four years ago he had scarlet fever and ever since then he has been incapable of education. He cannot learn his alphabet, but he can count up to thirty. He cannot write either letters or figures, but he has a good idea of drawing ; for instance, if asked to draw a house, he does it slowly, but surely. He is infantile—his arms do not come down to the iliac crests.

I also show you a child of nine years who presents features of considerable interest.

Illustrative case shown :—

B. C.—Aged 9. This interesting little girl is well nourished, and is well up to the standard of height, being 4 ft. 2 in. (average for girls 4 ft. 1 in.), her weight is 4st. 3lbs. (average 3st. 13½lbs.). Notwithstanding this she was a backward child and up to the age of four years could neither walk or talk properly, nor help herself. Her parents could only understand a few words such as a baby of eighteen months or so would be able to say, and she had to be dressed like an infant of six months old. Up to a few weeks ago her speech remained very indifferent, and she still played like a little girl of about four years of age. During the past year or two her motor centres have become educated, and she has grown into a big, strong child. Her intelligence, however, is very slow—she speaks imperfectly, she understands imperfectly and she still remains very dependent upon her mother for assistance in dressing, washing, &c. She cannot remember the names of common objects, and asked to perform some stated action she cannot do it, e.g., asked to bring a flower or a doll from a chair at the other end of my room, she could not grasp what was meant. About five weeks ago I started giving her thyroid, with the result that a most remarkable brightening of her intelligence has taken place. She is already understanding better, and her memory is improved—she responds much more quickly when requested to do things. She is an example of a chemical inco-ordination and in all probability will improve immensely under treatment and become capable of education.

These cases are not like cretins which require to have thyroid substance (for instance) given them all their lives, for whenever the developmental processes are roused and the general nutritive conditions attended to, things generally go on normally without further need for interference. They illustrate how a chemical inco-ordination may be dealt with and corrected and how the mental acumen and capacity for education become rapidly improved as development advances. There are many grades of these cases to be found among older children, and there is not the slightest use in trying to educate them until the cellular chemistry and environment has been put to rights. The surgeon corrects deformity of limb and muscle by mechanical orthopoedics, but these cases constitute a chemical deformity and their successful treatment depends upon a chemical orthopoedics carried out on the lines concerning which I have spoken.

While dwelling upon this subject one is much tempted to wander into paths of speculation concerning the effects of over-stimulation or over-education in the way of perverting normal function and normal character. These chemical problems have a far-reaching importance and certainly have much to do with the stamping of character. In the child the chemistry is the chemistry of a child, and it differs entirely from that of the man or woman into which it subsequently develops. Set the chemistry going of the dull, apathetic, backward, ill-grown child by augmenting the supply of some deficient substance, necessary for the stimulation of the metabolism of its tissues, and you convert it into a bright, cheerful, playful and normally growing being, which goes on developing after the treatment is stopped. The tissues learn the trick, so to speak, and apparently themselves promote the reactions which provide for their metabolism. So in the adult—some stimulus may give rise to a progressive change in function or character which was lying dormant. We know something about the action of the

hormones which pull the trigger and set a secretive or perhaps an involuntary muscular function going, and we recognise their chemical nature; we also know that suggestion will promote the activity of glands, and that these chemical processes may be inaugurated through a mental stimulus. In another paper I have indicated my conceptions of the relationships which exist between certain psychoses and neuroses and the climacteric periods of life, and how they depend upon chemical inco-ordinations, due to the over-production of some secretion on the one hand or its under-production (relative or actual) or perversion on the other. It also seems possible that in a healthy person the over-stimulation of some one function may lead to its acting in a disproportionate way owing to the establishment of a disproportionate chemistry, a state of affairs perhaps accounting for obsessions of various kinds, which may be very hard to control. The influence of the mind upon these chemical phenomena should not be forgotten; it quite possibly accounts for many acquired characteristics, for mannishness in women, and one might even suggest for the psychic conditions which are associated with militancy, and for a number of other qualities and characteristics in both sexes. It is quite conceivable that in many of the so-called functional diseases, which express themselves through the nervous system, the upset of co-ordination is essentially the result of a disorganised cellular or secretive chemistry, and to this extent they may be more organic in their nature than is commonly supposed, and they form a group concerning which the bio-chemist will, I have no doubt, be able to enlighten us in days to come, when the problems which have to do with cell stability are better understood. In education and environment we have, then, valuable and powerful forces, capable of influencing what are really organic functions, but in utilising these forces, while recognising that there are average standards of intelligence at varying ages among school children, which enable us to group them, we have

also to bear in mind that the essential to knowledge being the individual, i.e., the person or self and his or her capabilities, we must regard many children individually, there being numerous instances of idiosyncracy of intellect, or where some special circumstance, such as the presence of a disease or of a physical disability, makes it necessary for us to vary our methods of inculcating knowledge.

It is in connection with these latter, the invalid children, that in conclusion I shall say a few words. Some years ago, had my opinion been asked as to whether it was wise or not to attempt to associate the systematic education of invalid children with their medical or surgical treatment, I should have said "no," on the ground that it was better to conserve energy for the processes of repair. Experience, however, has proved that instead of hindering our work as medical men, education has a certain therapeutic value. A good deal of attention is paid to the sick child, and the greater part of its time, whether in the hospital or at home, is spent in an atmosphere which directs its thoughts to itself and its troubles. The visits of the medical men, the attentions of the nurses, the efforts to amuse and to pass the time all serve to remind the child that it is not as other children are. Suffering from a more or less chronic ailment, there is nothing worse for it than to be deprived of some of the daily occupations which other children have. We constantly observe among these cases that whenever pain is relieved or some local disability, even quite a painless one, is corrected, an immediate brightening up of the intelligence begins to occur. Take for example, a child suffering from spastic paralysis in its legs ; it has not walked perhaps for years, and it often has the appearance of being mentally deficient. When the surgeon corrects the spastic condition and enables the patient to get on to its legs and to learn to use them, the intelligence improves and approximates more nearly to the normal, because the deflected and inco-ordinated nervous

energy is released, as I have previously explained; and the giving of the child something to do, not only in the way of learning to walk, but also in the way of manual occupation and other objective education, further stimulates its intelligence, and leads to control of co-ordination of the various centres. Such a case furnishes a single example of which many other types are familiar to us.

Illustrative case shown :—

F. M.—Aged 5. A case of spastic paralysis. The child was practically an imbecile until two years ago—i.e., when she was three years of age she was quite unable to speak—she moved her limbs about in an aimless kind of way. The legs were paralysed, and the paralysis has been put right by Mr. Robert Jones. Almost immediately afterwards a brightening of the intelligence took place and she has begun to speak and to stand. This is an example of deflected energy being released, and the general backwardness which is associated with these cases has been greatly relieved by giving thyroid gland substance, which she has taken from before the time of the operation.

Illness promotes self-consciousness, because constantly to know a thing is to become self-conscious of it, and this frame of mind means that other forms of knowledge than those affecting or appertaining to the illness are apt to become dwarfed, and a kind of backwardness results, simply due to a lack of cultivation of faculties which may be potentially quite active. The child may possess knowledge unawares, and education draws out this unknown knowledge and leads to the lessening of self-consciousness and to a healthier and more co-ordinated intelligence. It is on this account that at the Royal Liverpool Country Hospital for Children we have favourably considered the question of adding certain types of education to our armamentarium. Tissue metabolism, growth and nutrition, all of which are necessary for the processes of repair, are favoured by the constant open-air life which our children lead at Heswall. The change of scene and the beauty of the surroundings also bear their share in working the oracle of recovery, and now we have added the stimulants for the intelligence which are provided by the Board of Education. The methods are not of a worrying

or standardising description, and they do not involve a great deal of reading, writing and arithmetic. They appeal to us on account of their physical, manual and objective characters. Variety is provided and routine is avoided, the principle that the strange or unaccustomed excites attention while the familiar passes unregarded being thereby fulfilled. Part of the time is spent in doing manual work, basket-making, brush-work, paper and cardboard work, netting and so forth, and later on some other extensions will probably be incorporated, such as free play, games of an organised character and out-door occupations; and it is quite possible that some lessons suitable for little girls, in the way of practical hygiene and simple domestic subjects, may be added. All of these measures help to equalise the intellectual and physical intelligence and to co-ordinate the motor and sensory functions of the child by directing its attention away from its troubles and so bringing it into conditions which serve to remind it that it has far more of the qualities which belong to health than of those which appertain to the disease from which it may be suffering. Hence it is that I regard with favour the work of the Board of Education in its relation to the invalid child, believing, as I do, that there is a therapeusis associated with any effective measures which help to restore co-ordination, whether the inco-ordination of function be physical, intellectual or more manifestly chemical in its nature.

FIG. 1. The Port Erin Biological Station from the North East.

[From a photograph by Prof. F. J. Cole.

THE

MARINE BIOLOGICAL STATION AT PORT ERIN

BEING THE

TWENTY-SEVENTH ANNUAL REPORT

OF THE

LIVERPOOL MARINE BIOLOGY COMMITTEE.

This year is the Coming of Age of the Port Erin Biological Station, not, it is true, of the present building which is only eleven years old, but of the Biological Station as an institution founded and maintained at Port Erin by the Liverpool Marine Biology Committee.

The first cottage with which the Station started was built and opened for work in 1892, the second little house was added to it the following year, the present much larger building (fig. 1) was erected in the winter of 1901 and was first used in the summer of 1902 ; and finally the new research wing was added in 1910 and has been fully occupied in vacations during the last three years. For a few years previous to that time the number of workers in the laboratories ranged from 30 to 40 individuals in the year, but from 1910 onwards the numbers have been nearly doubled :—

1910	57	1912..............	74
1911	60	1913..............	72

All the available work-places in the institution have really been more than comfortably filled during the Easter vacations (the favourite time with both students and researchers) of the last three years. In 1912 the place was too full of workers, which is perhaps partly the reason why we had not quite so many this year.

Some extension of the laboratories is, therefore, once again urgently called for. A certain amount of very welcome relief was obtained last year by running a wooden partition across the

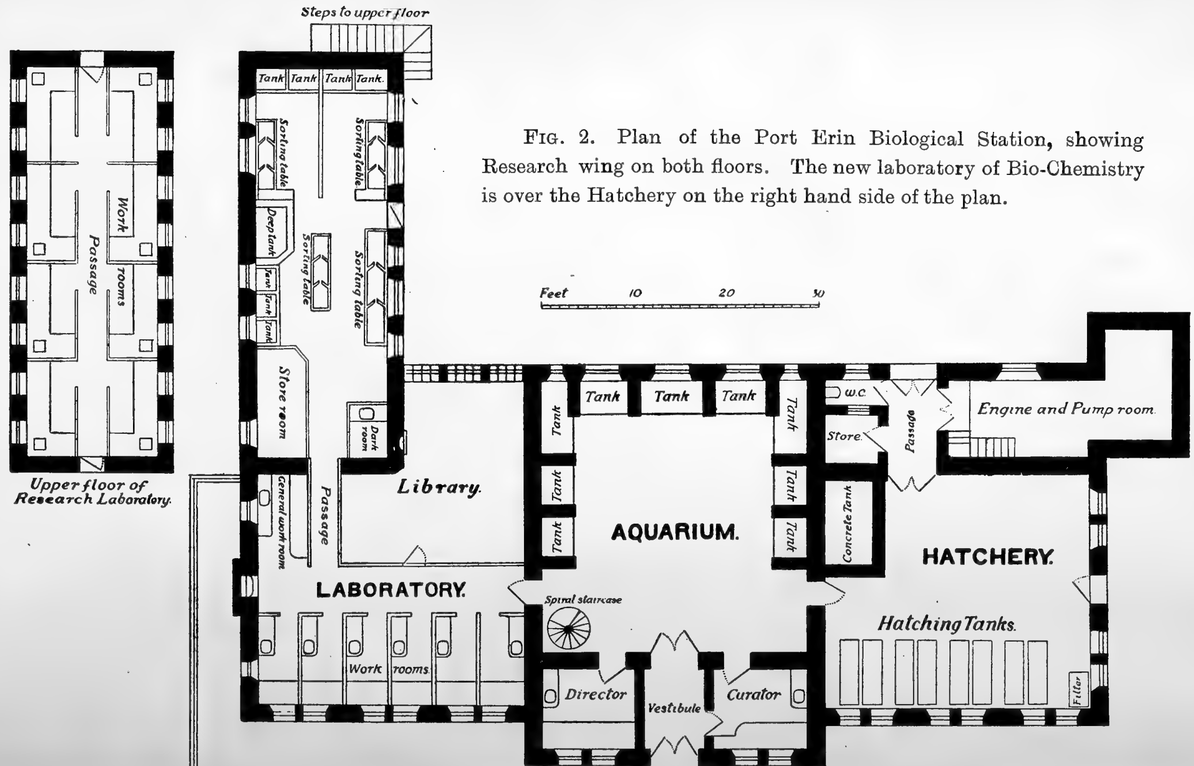


Fig. 2. Plan of the Port Erin Biological Station, showing Research wing on both floors. The new laboratory of Bio-Chemistry is over the Hatchery on the right hand side of the plan.

large apparatus room over the fish hatchery, so as to make the front portion, overlooking the bay, available as a research laboratory for bio-chemistry. This new laboratory, simply fitted up with work benches and shelving, sinks, water-taps and gas supply, has been occupied from time to time by Professor Moore, Dr. Prideaux and Messrs. Mottram, Whitley, Edie, Evans and G. A. Herdman in their work on the nutrition of marine invertebrates and on the seasonal changes in the sea-water. The room corresponds practically to the space below the word HATCHERY on the right-hand side of the plan shown in fig. 2.

The usual Easter vacation courses in Marine Biology were carried on during April under the guidance of the teachers in the Zoology and Botany departments of the University of Liverpool.

Other groups of senior students came from Reading (under Professor Cole's direction), from Manchester, from Birmingham, and we had also a few researchers from Cambridge and elsewhere—including Dr. Th. Mortensen, from Copenhagen, who came to study our Port Erin Echinoderm larvæ, a subject which we hope to illustrate by publishing this winter, as an L.M.B.C. Memoir, the series of drawings which Mr. Chadwick has been accumulating for some years.

Other special investigations carried on at Port Erin during the year will be referred to in more detail later on in this report.

The usual collecting expeditions on sea and shore were arranged during the Easter vacation. Figures 3 and 4 show characteristic groups on such occasions—in fig. 3 listening to a discourse at Port St. Mary and in fig. 4 collecting on the sea-shore at Fleshwick bay.

As on previous occasions, I shall first give the statistics as to the occupation of the " Tables " during the year, then will follow the " Curator's Report," and the reports that have been sent to me by various investigators on the work they have done,

Fig. 3. Students at a field-demonstration.
[Photo by Prof. W. J. Dakin.

Fig. 4. Shore collecting at Fleshwick Bay.
[Photo by Prof. F. J. Cole.

and, finally, I shall describe some of the researches in which I have been myself taking part along with colleagues and assistants both at Port Erin and elsewhere.

The Station Record.

Upwards of seventy researchers and students have occupied the Work-Tables in the Laboratories for varying periods during the year, as follows :—

Dec. 28th, 1912, *to Jan. 6th,* 1913.	Professor Herdman.—Tunicata.
Feb. 13*th to* 17*th.*	Professor B. Moore.—Bio-Chemistry.
March 1*st to* 3*rd.*	Professor Herdman.—Official.
March 15*th to* 29*th.*	Mr. C. W. Lowe.—General.
March 15*th to* 29*th.*	Mr. J. H. Lloyd.—General.
March 20*th to April* 2*nd.*	Professor F. J. Cole.—Educational.
„	Mr. Malpas.—General.
„	Mr. W. Kings.—General.
„	Miss N. Eales.—General.
„	Miss D. Coward.—General.
„	Miss M. Snoxell.—General.
„	Mr. H. L. Hawkins.—Echinodermata.
„	Mr. R. W. Palmer.—General.
„	Mr. H. W. Hyde.—Geology.
March 31*st to April* 8*th.*	Professor Harvey Gibson.—Educational.
„	Professor Reynolds Green.—Research.
„	Miss L. Nash.—Marine Algæ.
„	Miss E. M. Blackwell.—Marine Algæ.
„	Miss A. G. Wilkinson.—Marine Algæ.
„	Miss E. M. Mather.—Marine Algæ.
„	Miss G. L. Hanna.—Marine Algæ.
„	Miss D. Jones.—Marine Algæ.
„	Miss H. Clarke.—Marine Algæ.
„	Mr. R. H. Blair.—Marine Algæ.
„	Miss D. Lamble.—Marine Algæ.
„	Miss I. L. Millican.—Marine Algæ.
„	Miss L. Higson.—Marine Algæ.
„	Mr. J. W. Hopkinson.—Marine Algæ.
March 31*st to April* 14*th.*	Miss E. Gregory.—General.
„	Miss I. Gregory.—General.
„	Miss K. Clegg.—General.
„	Mr. E. Holden.—General.
March 31*st to April* 21*st.*	Professor Herdman.—Plankton.
„	Mr. G. A. Herdman.—Chemistry of Sea-water.
„	Mr. H. G. Jackson.—Plankton.
„	Mr. S. T. Burfield.—Sagitta.
„	Miss E. L. Gleave.—Archidoris.
„	Miss F. Tozer.—Nerves of Fishes.
„	Miss M. Knight.—Marine Algæ.
„	Miss R. Robbins.—General.
„	Miss H. M. Duvall.—General.

March 31*st to April* 21*st.*	Miss E. Lewis.—General.
,,	Miss C. M. P. Stafford.—General.
,,	Miss B. Norbury.—General.
,,	Miss M. Davies.—General.
,,	Miss A. Kay.—General.
,,	Miss E. M. Smith.—General.
,,	Miss F. Robinson.—General.
,,	Miss M. Bradley.—General.
,,	Miss M. Udall.—General.
,,	Miss U. Little.—General.
,,	Miss A. Garside.—General.
,,	Miss J. Upson.—General.
,,	Miss E. Edmondson.—General.
,,	Miss G. Clegg.—General.
,,	Miss O. G. Ellams.—General.
,,	Miss D. E. Payne.—General.
,,	Miss D. Thornton.—General.
,,	Miss G. Platt.—General.
,,	Miss R. C. Bamber.—Rotifera.
,,	Mr. J. Erik Hamilton.—Plankton, &c.
,,	Mr. R. J. Daniel.—Plankton, &c.
,,	Mr. R. Douglas Laurie.—Amphidinium.
,,	Mr. V. H. Mottram.—Physiology.
April 8*th to* 10*th.*	Professor B. Moore.—Bio-Chemistry.
May 10*th to* 13*th.*	Professor Herdman.—Plankton.
,,	Professor B. Moore.—Bio-Chemistry.
May 20*th to June* 3*rd.*	Dr. F. Ward and Assistant.—Photography of Marine Animals.
June 14*th to* 16*th.*	Professor Herdman.—Official.
,,	Professor B. Moore.—Bio-Chemistry.
,,	Dr. E. B. R. Prideaux.—Sea-water.
,,	Professor A. Dendy.—General.
July 14*th to* 25*th.*	Mr. Holden.—Marine Algæ.
July 17*th to* 20*th.*	Dr. Th. Mortensen.—Echinoderm Larvæ.
July 19*th to Aug.* 9*th.*	Mr. T. Monaghan.—Lobster Culture.
Aug. 11*th Sept.* 4*th.*	Mr. A. E. Kidd.—Lobster Culture.
Aug. 26*th to Sept.* 13*th.*	Mr. G. J. Hill.—General.
Aug. 29*th to Sept.* 8*th.*	Professor Herdman.—Plankton.
,,	Mr. G. A. Herdman.—Chemistry of Sea-water.
Oct. 27*th to Nov.* 4*th.*	Miss A. Porter.—Parasitology.
July to Sept. on various occasions.	Mr. W. Bygrave.—Herrings and Plankton.

The "Tables"* in the Laboratory were occupied as follows:—

Liverpool University Table :—

Professor Herdman.	Mr. H. G. Jackson.	Miss E. M. Blackwell.
Professor Harvey Gibson.	Mr. V. H. Mottram.	Miss E. L. Gleave.
Professor B. Moore.	Mr. R. J. Daniel.	Miss R. C. Bamber.
Mr. R. Douglas Laurie.	Mr. J. Erik Hamilton.	Miss H. M. Duvall.
Mr. S. T. Burfield.	Miss M. Knight.	Miss F. Tozer.
Miss R. Robbins.	Dr Prideaux.	

*Since the new research wing has been added several distinct apartments are generally available for the accommodation of the investigators assigned to any one of the University "Tables."

Liverpool Marine Biology Committee Table :—

Professor Reynolds Green.	Dr. F. Ward.	Mr. G. A. Herdman.
Dr. Th. Mortensen.	Mr. G. J. Hill.	Mr. J. W. Hopkinson.

Manchester University Table :—

Miss E. Gregory.	Miss K. Clegg.	Mr. E. Holden.
Miss I. Gregory.		

Birmingham University Table :—

Mr. C. W. Lowe.	Mr. J. H. Lloyd.

University College, Reading, Table :—

Professor F. J. Cole.	Mr. Malpas.	Miss N. Eales.
Mr. H. L. Hawkins.	Mr. W. Kings.	Miss D. Coward.
Mr. R. W. Palmer.	Mr. H. W. Hyde.	Miss M. Snoxell.

The following students of Liverpool University occupied the laboratory for periods varying from a fortnight to three weeks during the Easter vacation, and worked together under the supervision of Professor Harvey Gibson, Miss M. Knight, Miss E. M. Blackwell, Mr. R. Douglas Laurie and Mr. Burfield:—

Miss L. Nash.	Miss E. Lewis.	Miss U. Little.
Miss A. G. Wilkinson.	Miss C. M. P. Stafford.	Miss A. Garside.
Mr. E. M. Mather.	Miss B. Norbury.	Miss J. Upson.
Miss G. L. Hanna.	Miss M. Davies.	Miss E. Edmondson
Miss D. Jones.	Miss A. Kay.	Miss G. Clegg.
Miss H. Clarke.	Miss E. M. Smith.	Miss O. G. Ellams.
Miss D. Lamble.	Miss F. Robinson.	Miss D. E. Payne.
Miss I. L. Millican.	Miss M. Bradley.	Miss D. Thornton.
Miss L. Higson.	Miss M. Udall.	Miss G. Platt.
Mr. R. H. Blair.		

Curator's Report.

Mr. Chadwick reports to me as follows :—

"The number of individual workers who resorted to our laboratories during the past year—seventy-two—is practically the same as that (seventy-four) of the previous year ; and the accommodation afforded was again fully utilised during the Easter vacation.

"The apportionment, by partition, of rather more than half of the large store room above the fish hatchery to the purposes of a chemical and physiological laboratory has afforded Professor Moore and his assistants and other workers much better facilities for their work on the nutrition of marine animals and on the chemistry of sea-water. The work done during the Easter vacation followed closely on the lines of previous years. Collecting expeditions were organised to various parts of the neighbouring coast, demonstrations of oceanographic work were given on the S.Y. 'Runa,' and evening lectures in the laboratory were taken by Professor Herdman, Mr. Douglas Laurie and the Curator.

"The number of visitors to the Aquarium during the year—16,607—is a record one. It represents an advance upon that of 1912 of about 2,400, and upon that of 1907, the highest previous number, of about 1,000. One thousand and forty-two copies of the new edition of the Guide to the Aquarium were sold. This number also is substantially larger than that of any previous year.

"During the winter (November to March) the Curator has, as in previous years, given frequent demonstrations and lantern lectures on Nature Study and Marine Biology (1) to a class of about 20 boys brought from the local Higher Education School, and (2) to parties of children from the local and some other insular schools.

"The work of the fish hatchery was begun on Feb. 17th, with 350 healthy plaice in the spawning ponds. The hatching apparatus was set in motion with a first batch of 88,200 eggs; and by March 13th, when the first lot of larvæ were ready for liberation, the number of eggs incubating in the hatching boxes was 2,344,000. Quantities of eggs exceeding half a million in number were skimmed from the pond on March 18th and 31st, and on April 8th and 11th respectively; and upwards of 400,000 were collected on March 22nd and April 2nd respectively. On

March 31st the number collected was 976,500, the largest hitherto recorded on one day. The numbers continued to exceed 100,000 per day until April 15th, after which there was a considerable falling off.

"The spawning season extended over 74 days, and the total number of eggs collected from the ponds was 8,780,000; while the total number of larvæ hatched and set free was 7,706,800. The great majority of these were taken out to sea by Professor Herdman in his steam yacht 'Runa.' One large consignment, numbering 1,439,700, was set free off Port St. Mary. The rest were distributed about five miles out to sea to the West of Port Erin.

"The Hatchery Record, giving the number of eggs collected, and of larval fish set free on the various days is as follows:—

Eggs collected.	Date.	Larvæ set free.	Date.
284,500	.. Feb. 17 to 22	236,300	.. March 13
370,300	.. ,, 24 to 28	435,800	.. ,, 18
313,700	.. March 1 and 3	289,700	.. ,, 22
148,000	.. ,, 4 and 5	128,000	.. ,, 24
597,500	.. ,, 8 to 11	509,800	.. ,, 29
530,000	.. ,, 12 and 13	430,600	.. April 2
924,000	.. ,, 14 to 20	850,800	.. ,, 7
495,600	.. ,, 22	413,000	.. ,, 8
500,800	.. ,, 24 to 26	445,000	.. ,, 12
228,800	.. ,, 27 and 29	190,000	.. ,, 14
1,635,900	.. ,, 31 to April 2	1,439,700	.. ,, 17
315,000	.. April 3 and 7	257,200	.. ,, 18
1,883,700	.. ,, 8 to 14	1,651,800	.. 21 & 24
276,100	.. ,, 15 to 17	204,400	.. ,, 28
276,100	.. ,, 21 to May 1	224,700	.. May 10
8,780,000=Total eggs.		7,706,800=Total larvæ.	

"The plaice hatching season over, attention was turned to the acquisition of a stock of 'berried' lobsters, in anticipation

of further experiments in lobster culture during the summer and autumn. The lobster pond was carefully cleansed, and, by piling together a number of large stones and bricks at the deeper end, hiding places were prepared for the lobsters.

"By the middle of June six 'berried' ones, with eggs in advanced stages of development, had been purchased from local fishermen, and on various dates up to and including Sept. 3rd 12 more were brought in, making a total of 18, exactly the same number as were obtained last year. The eggs of the first few being well advanced, they were put into the uppermost compartments of the hatching tanks in anticipation of the early appearance of larvæ, and, in view of Mr. Gunn's results last year, of continuing the use of the hatching tanks for rearing purposes.

"The old trouble—premature shedding of the eggs by the parent lobsters—soon made its appearance, and, as it threatened to result in considerable loss, I eventually decided to transfer the lobsters to the pond. This was done, and as new ones were brought in they were at once put into the pond. So far as could be ascertained from careful inspection, no further egg shedding occurred; and I am now satisfied that in future 'berried' females may be kept in the pond indefinitely, without fear of a recurrence of this annoying trouble.

"The first larvæ made their appearance in the pond at the end of June, and by the end of the first week in July considerable numbers were swimming about actively and appeared to be doing well. Some of these I transferred to the hatching boxes; but the majority were left in the pond and fed daily upon minced liver of crab.

"On July 19th Mr. T. Monaghan came over from the University of Liverpool to undertake the work of lobster culture; and on the 21st, when he began work, there were nine 'berried' lobsters in the pond, and several thousands of first,

second and third stage larvæ. I now had great hopes that we were within reach of a more substantial advance than we had hitherto attained. A few days later, however, we noticed that the larvæ, especially those in the third stage, were disappearing, and on draining off most of the water from the pond, their decomposing remains were found in numbers on the bottom. I cannot offer any explanation of this. Large quantities of water were pumped into the pond daily ; and all unconsumed food was removed as thoroughly as possible. After this the newly hatched larvæ were removed from the pond every morning, counted, and placed in the hatching boxes. This, of course, added considerably to T. Monaghan's work. According to a statement which he left with me he dealt with 3,943 larvæ, of which 10 reached the lobsterling stage before he left on August 9th.

"Mr. A. E. Kidd, also from the Liverpool University laboratory, began work on August 11th and left on Sept. 4th. On the lines described above he dealt with 4,038 larvæ ; and on the date of his departure 120 lobsterlings had been set free. During the second week in September the eggs of the lobster placed in the pond on the 3rd of that month began to hatch out, and I took the earliest opportunity of transferring 1,000—all but a very small number of them—to the hatching boxes. In spite of the devotion of many hours to the care of them, only eleven have reached the lobsterling stage. Though the conditions, temperature, &c., have remained much the same as they were in the late summer, the development of these larvæ has proceeded at a slower rate than that of those dealt with by Messrs. Monaghan and Kidd. I fed them daily on minced mussel (*Mytilus edulis*), and satisfied myself that they partook of it. In addition to this food I found that Copepoda were constantly present in fair numbers in the water flowing through the hatching boxes, so that there can be no question of the larvæ having died for want of sufficient food.

"It is impossible to state the total number of larvæ hatched this year. Messrs. Monaghan and Kidd and I together dealt with nearly 9,000 in the hatching boxes; and I am not overstating the number when I say that an additional 3,000 to 4,000 were lost by death in the pond before we began to count and transfer them to the hatching boxes. The total number of lobsterlings reared to date is 170. Of these 154 were set free, and I am now trying to rear the remaining ones to the adult condition. During the season of 1912 Mr. Gunn dealt with 8,227 larvæ. Of these 3,107 were set free in the first, second and third stages. Of the remaining 5,120, three hundred and thirty-three were reared to the lobsterling stage, and all but a few set free.

"I am now satisfied that so far as securing the retention of the eggs upon the swimmerets of the parent lobsters, and the subsequent hatching of practically all the eggs is concerned, the pond fulfils all requirements; but we still have difficulties to overcome in rearing the larvæ through their successive moults to the lobsterling stage."—H. C. Chadwick.

Other Reports on Work.

Professor Cole and his party of colleagues and students from Reading were chiefly occupied, as usual, in observing and collecting, and in making injected preparations of various invertebrata for their College Museum. Professor Cole reports to me:—"Our Easter party this year consisted of 9 persons, and the work was as usual largely educational. We brought back for the College Museum, however, a large and magnificent specimen of the Medusa *Rhizostoma pulmo*, which we have since successfully displayed in a specially constructed tank of teak and plate glass. We also made a number of interesting injected specimens for the Museum, of which a beautiful injection of the dermal gills of Asterias, since imitated in other museums, may be specially mentioned."

Professor Harvey Gibson and Dr. Reynolds Green commenced last year a series of experiments in our open-air concrete tanks and in a part of the spawning pond, on the toxicity of certain compounds to algal gonidia, and the conditions of their germination on various substrata. These have been continued during the present season, but the results are not sufficiently far advanced to warrant publication.

Mr. Burfield has started work on the remarkable pelagic "Arrow-worm" *Sagitta bipunctata* (fig. 5), with the object of producing an L.M.B.C. Memoir on the subject. He was mainly occupied at Port Erin in collecting and preserving material from the plankton collections, and in recording the statistics of distribution.

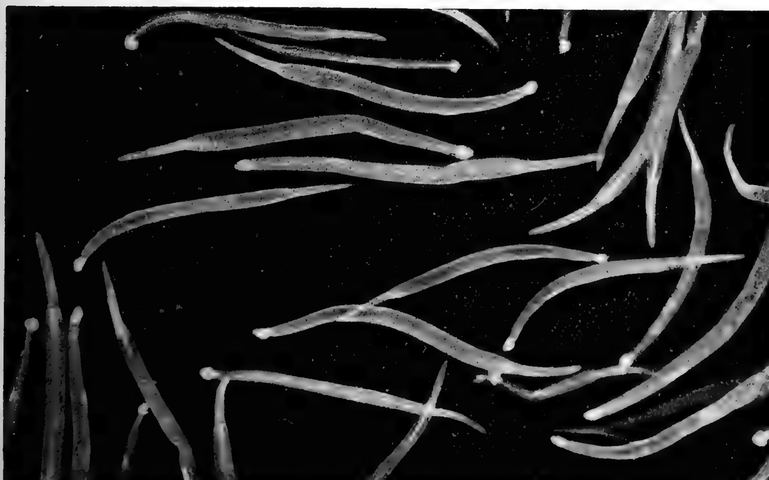


FIG. 5. The Arrow-worm, *Sagitta bipunctata*.
[Photo by Mr. A. Scott.

Mr. H. G. Jackson, M.Sc., acted as my Assistant in the plankton investigation from the yacht during the Easter vacation. The results obtained will be given in full in the next

Lancashire Sea Fisheries Report and so need not be further referred to here. The rest of Mr. Jackson's time at Port Erin was occupied in collecting material for his work on the larvæ of Higher Crustacea. He examined the various plankton gatherings with the object of tracing the young stages of crabs and lobsters, shrimps and prawns, and other allied animals throughout their life-histories, and also in their distribution over the district and throughout the year. Mr. Jackson published a first report on this subject in the Lancashire Sea Fisheries Report for 1912 and has in preparation a more detailed account.

Mr. V. H. Mottram continued his work on the fats of marine animals. In the Easter vacation of 1913 he made collections of typical carnivorous and phytophagous molluscs with a view to comparing the fatty acids of the two groups. At the same time further material was obtained to complete the work done in 1912 on plaice and mussels. The work is still in progress, and no results can yet be stated.

Mr. Chadwick, who has been identifying the rarer Echinodermata obtained during the cruise of the "Runa," reports as follows :—"Here is a list of your 'Runa' Echinoderms* :—

Antedon phalangium (J. Müll.).
Antedon bifida (Penn).
Antedon tenella (Retzius).
Asterias muelleri (Sars).
Pteraster militaris (O. F. Müll.).
Ophiocnida brachiata (Montagu).
Echinus acutus, Lamk.
Phyllophorus pellucidus (Düb. and Kor.).

"I am more dissatisfied even than I was last year as to the specific distinctness of *Phyllophorus pellucidus* and *P. drummondi*. Nothing short of careful records of the appearance of

* Only the more uncommon forms. A number of other, common species were obtained.

the living animals will settle this. Speaking of *P. pellucidus*, Bell says— 'Tables generally distributed in the body-wall, but not numerous.' The truth is that they are closely packed, apparently in every part of the body-wall. I doubt whether the distinction he draws between the 'tables' of *P. pellucidus* and those of *P. drummondi* is valid."

Miss Tozer reports her research as an attempt to investigate the sensory nerve endings in the eye muscles of the fish, *Gadus virens*, by means of the methylene blue method. This attempt yielded no very definite results as the method was only partially successful. It only revealed a few very fine myelinated nerve fibres and non-myelinated endings near the tendon muscle junction, and gave no indication of the total supply.

Miss A. Porter, D.Sc., spent some time in the late autumn at Port Erin working at parasitology. She examined such fish, molluscs and other invertebrates as were available at that time, and found various interesting parasites at which she hopes to do further work at Port Erin in the future.

Mr. W. Bygrave, B.A., formerly of Cambridge and the Marine Biological Laboratory at Plymouth and now Science Master at King William's College, Castletown, is from time to time pursuing research work at the Port Erin Laboratory. The investigation on which he has started consists in comparing the stomach contents of samples of herring, obtained in the commercial fisheries round the Island, with the plankton occurring at the same time at the same locality. We have made arrangements with the skipper of a fishing boat to preserve for us the necessary herring samples, and at the same time to take hauls of the plankton net with which we have supplied him. These samples and gatherings are sent to the Port Erin Laboratory to await the detailed comparison which Mr. Bygrave will make, both as regards their bulk and their microscopic

nature. These samples have been collected as frequently as possible during the greater part of the summer, and most of them are from a locality about 10 miles West of the Chicken Rock Lighthouse. On such occasions two gatherings of plankton were obtained by means of a tow-net of fairly coarse mesh, which was lowered in each case to the depth of the bottom of the herring nets and was then hauled up slowly to the surface, these plankton hauls being taken at the same time that the herrings were being caught. Each herring sample consists of the stomachs of ten fish taken at random from each haul and preserved in formalin.

Dr. Francis Ward paid a visit to the Biological Station, in May and June, 1913, to confirm in the clear waters of the Irish sea certain observations made in special tanks at Ipswich. He wished also to study the appearance of numerous forms of marine life, when viewed as if from below the surface of the water, and lastly to trace the connection as a concealing factor—if it existed—between the electric blue pigmentation seen on such marine forms as *Homarus vulgaris, Portunus puber*, etc., when these crustaceans are seen from below the surface, and the blue reflection from various red-brown sea-weeds, e.g., *Chondrus*, when these sea-weeds are seen against a dark surface with the top light cut off.

A special tank was arranged at the back of the station, and in this was built up an artificial rock-pool with natural stones and weeds taken from the sea. Various anemones and other forms of marine life were viewed in this tank from a dark chamber at the sides. This enabled everything to be seen by an entirely natural illumination. The great value of white as a concealing factor among marine fauna was demonstrated, the white anemone reflecting the colour of its surroundings as soon as the top light was cut off.

The Minute Life of the Sea-beach.

In continuation of the observations which have been recorded in the last two Reports as to the occurrence of the Dinoflagellate *Amphidinium operculatum*, in two distinct forms, from time to time, upon the beach at Port Erin, I have only now to add :—

(1) That Mr. R. D. Laurie, while at Port Erin in April, made a series of observations designed to test the question, raised by his observations at Hoylake,* as to whether certain rhythmic movements of the patches of the organisms are due to direct response to environmental stimuli or to habit. The former view was supported. The patches have a daily rhythm of appearance above and disappearance below the surface of the sand, and the times of these movements can be very fairly calculated from a knowledge of the actinic value of the light and the condition of the tide. The optimum light intensity is a diffused condition, a strong light is avoided. The influence of the tide, apart from light, was studied during the night and the organisms were seen to disappear shortly before the incoming tide reached them and to reappear as soon as the tide receded from their area. The interaction of light and tide stimuli produce a daily and also a fortnightly rhythm, very little, if any, of which is due to habit. Under experimentally altered conditions a new rhythm supervenes.

(2) That during the last year our knowledge of the range of distribution of *Amphidinium* on the British Coasts has been considerably enlarged—as may be seen from the following letter to "Nature," which appeared on July 31st, 1913, p. 558 :—

"Biological readers of 'Nature' will perhaps recollect the

*Mr. Laurie also read a paper on the Bionomics of *Amphidinium* before Section D of the meeting of the British Association at Birmingham, in September.

record of the finding of the Dinoflagellate, *Amphidinium operculatum* (previously unknown in Britain), on the beach at Port Erin a couple of years ago. Since then it has been present in great abundance at Port Erin on many occasions; Mr. R. D. Laurie found it at Hoylake, near Liverpool, in February, 1913; two of our young Liverpool zoologists (R. J. Daniel and J. Erik Hamilton), now at the Belmullet Whaling Station, co. Mayo, inform me that they have noticed it on the shores of Blacksod Bay; and now I have to-day found it here in abundance, staining slightly in patches and streaks the beautiful white shell-sands of Iona.

"Both the forms found at Port Erin—viz., the shorter discoid (the typical *A. operculatum*) and the larger more ovate form, which I have described from Port Erin—occur here, associated with a few Naviculoid diatoms.

"It seems probable that this curious Dinoflagellate, known in the living state, so far as I can ascertain, to very few biologists, and previously recorded from only three or four far-distant localities, is really very generally distributed, and might be found by careful searching on many sandy beaches.—W. A. Herdman. S.Y. 'Runa,' Sound of Iona, July 20th."

The two forms of *Amphidinium* referred to in the above letter are shown at *h* and *i* in fig. 6, repeated here from last year's report. These two forms, differing so considerably in size, shape and movements, have now been found together at the following localities:—Port Erin (Herdman), Hoylake (Laurie), Cullercoats (Meek), Blacksod Bay (Daniel and Hamilton), and Iona (Herdman). If they prove, as seems quite probable, to be two distinct species, the small discoid one (*i*, in fig. 6) is *A. operculatum*, Clap. and Lach., and the larger more elongated form (*h*, in fig. 6), which was described and figured fully in last year's report (p. 31, fig. 9), will require a new name.

As a further contribution to this fascinating subject—the

minute living things infesting and colouring the sand-grains of our sea-beaches—I add here a further letter sent to "Nature" (see September 4th, 1913, p. 5) during our summer cruise in the Hebrides.

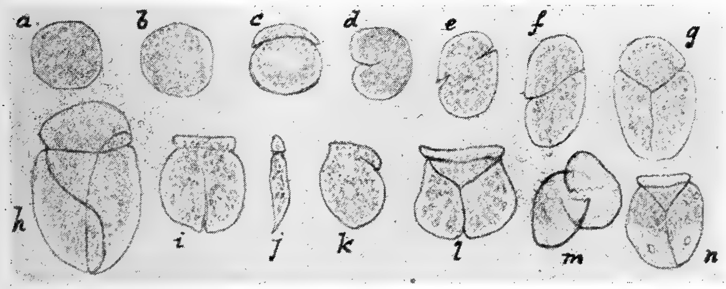


FIG. 6. Various forms of Amphidinium found on November 18th, 1912; *a* to *g* encysted and immature stages; *h* and *i* the larger (possibly new to science) and the shorter (typical *A. operculatum*) forms for comparison; *j* side view of *i*; *k*, *l* and *n* stages of short form; *m* a fission stage.

"A varied and interesting field of investigation awaits the microscopist who will make a detailed examination of the minute fauna and flora of apparently barren sands on the sea-shore. To-day, on landing at the island of Oronsay at low tide, the otherwise pure white sand was seen to be coloured pink in one area, for an extent of several yards, green a little further up the beach, and golden-brown in small patches here and there. On examining samples with the microscope the brown colour was found to be due to living diatoms (not Dinoflagellates in this case), naviculoid forms like Caloneis; the pink is formed of amorphous masses of fine granules in a jelly loosely adhering to the sand-grains, and may perhaps prove to be bacteria in a zoogloea state, while the green is caused by patches of a very simple alga (? a Coccophycid) made up of groups of rounded green cells in a single layer on the sand-grains. I have kept samples of all the organisms and will

submit them to a botanist for more precise identification. No *Amphidinium* patches were present so far as I could see. The variety of organisms present in the one little bay, the extraordinary abundance in each patch, and the brightness of the colour produced on the white sand were very striking, and seemed worthy of note.

"The colour was not in any of these cases due to the sand-grains themselves, which are mostly clear quartz with, as usual, a few black specks and some white shell fragments. Nor was there apparently any fresh-water on the beach, and certainly not any sewage or other source of impurity. It is a lonely, sandy bay, inhabited only by sea-birds and seals, and the nearest house is on the opposite side of the island at least four miles away by the coast. The sea-water seemed very clear, of salinity 26·5, and the sandy bottom could be seen from the yacht anchored in five fathoms.

"Diatom patches are no doubt abundant in many places; probably the simple green alga encrusting the sand-grains is known to botanists, and I have certainly seen the pink organism elsewhere. Probably other coloured patches due to micro-organisms are present on many beaches. It would be interesting to have them more thoroughly investigated—bio-chemically, if possible—by someone living on the spot, and able to study their changes day by day.—W. A. Herdman. S.Y. 'Runa,' Sound of Islay, August 27th."

I brought back samples of all these organisms, and Professor Harvey Gibson, to whom I handed them over, informs me that the pink one on the sand-grains is a Red Alga belonging to the Schizophyceæ, viz., *Microcystis elabens* (Meneghini), Kütz. Professor Gibson tells me that the identification has been confirmed by Professor Chodat, of Geneva, who adds that it is, however, a very small form of the species. This *Microcystis* has been found on the coast of Norway, but is apparently a new record for British seas.

I believe, however, that I have found it before, in a small bay to the North of East Loch Tarbert, on Loch Fyne—and the probability is that, like *Amphidinium*, it is much more widely spread and will be found in many localities if they are carefully searched.

CRUISE OF THE "RUNA" IN 1913.

In continuation of our practice of extending the marine biological investigations from the Irish Sea to the West Coast of Scotland during the summer vacation, we again this year organised an extensive cruise of nearly eight weeks (July and August) during which we sampled with dredge, tow-net and in other ways many of the water-ways between Port Erin and Stornoway in the Outer Hebrides. Most of the results of this cruise are being published elsewhere,* but there are a few

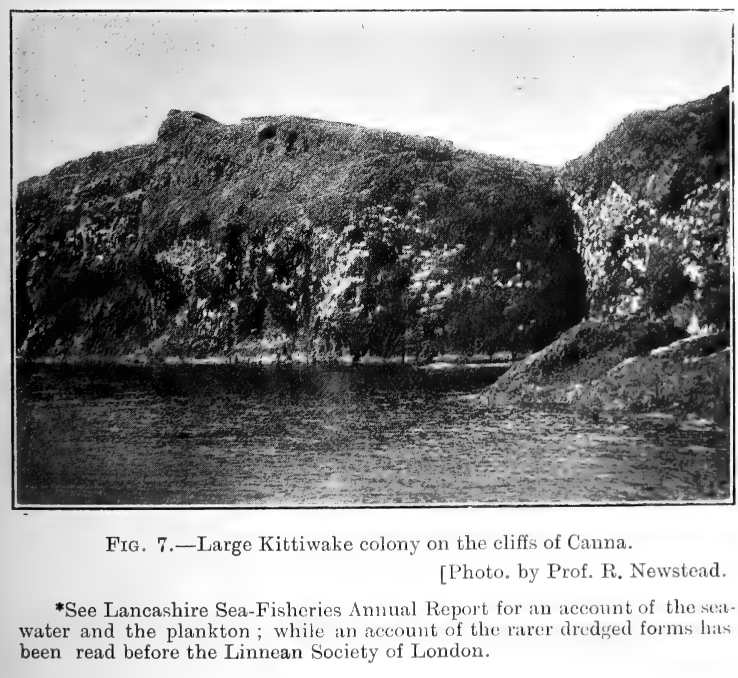


FIG. 7.—Large Kittiwake colony on the cliffs of Canna.
[Photo. by Prof. R. Newstead.

*See Lancashire Sea-Fisheries Annual Report for an account of the sea-water and the plankton; while an account of the rarer dredged forms has been read before the Linnean Society of London.

matters of more general biological interest that will be discussed below. First, however, let us say a few words on the organisation of the work.

During the early days of the cruise we had the advantage of having with us our two Naturalist friends, Mr. Alfred O. Walker, F.L.S., and Professor R. Newstead, F.R.S., both Past-Presidents of the Liverpool Biological Society. Mr. Walker was indefatigable and ingenious in capturing minute Crustacea (fig. 8), such as the Amphipoda, and he has supplied me with

Fig. 8.—Mr. A. O. Walker on the "Runa."

a list of over 100 species of Malacostraca obtained on the cruise, fourteen of which are names not contained in Canon Norman's list of the Crustacea collected by the British

Association Dredging Committee, from the Shetland seas, in the years 1861-67.

Professor Newstead, while primarily studying the sea-birds and the insects of the islands we landed on, took a keen interest in the dredging and tow-netting operations, and most kindly helped in all the scientific work. Several of the blocks illustrating this report have been made from photographs of the nests and haunts of Sea-birds taken by Prof. Newstead (see fig. 9). Throughout the cruise a great deal of

FIG. 9.—Nest of Merganser on an island in Loch Sunart.
[Photo by Prof. R. Newstead.

the work of collecting and preserving, recording and sketching was done by my wife, by our son George (who was responsible for all the physical observations—temperatures and salinities and samples of sea-water), our daughter Catherine (who collected, labelled and preserved the samples of dredged deposits to be examined for the Foraminifera), and our cousin Miss J. C. Ferrier, who gave valued assistance in keeping notes of the living animals, with both pen and paint brush, and

helped in various other ways. It is one of the advantages of such an investigating trip that everyone on board can be given some useful work to do. Another great pleasure is that one is able to collect material, which perhaps could not otherwise be obtained, for various scientific friends elsewhere who are at work on special problems.

Foraminifera.

The 24 canvas bags of mud, sand and other dredged deposits are now being examined by Messrs. Heron-Allen and Earland who are preparing a monograph on the British Foraminifera. These gentlemen have kindly supplied me with the following general notes on their results in regard to the first four samples examined. They have kindly enabled me to print also a list of the 259 species which they have picked out from these four samples to show how rich, in these minute and beautiful shells (see figs. 10 to 13), are many of the marine deposits of the Hebridean Seas.

S.Y. "Runa," 1913. Notes on Samples 1-4 of Deposits.

Sample 1.—From Lowlandman's Bay, Jura, 5 fms.

Bulk 500 c.c. of dark grey sandy mud. After washing, residue 115 c.c. 89 species from elutriated material.

Dominant forms very large *Rotalia beccarii*, large *Miliolidæ* and *Polystomella crispa*. Fine plastogam of *Truncatulina lobatula* and large *Verneuilina polystropha*. Notable absence of arenaceous forms. Very rich in Lagenidæ, especially *L. fasciata* and *marginata* (see fig. 11).

Sample 2.—From Sound of Mull, 20 fms.

A solid cake (254 c.c.) of black mud. Residue after washing, 5 c.c. 107 species (see fig. 10).

Most noteworthy form *Ammodiscus charoides* and *Haplophragmium glomeratum*. Commonest form *Bulimina marginata* of all types. Particularly rich in Nodosaria, especially *N. pyrula* and *communis* and *Roemeriana*. A very fine specimen of *N. filiformis*.

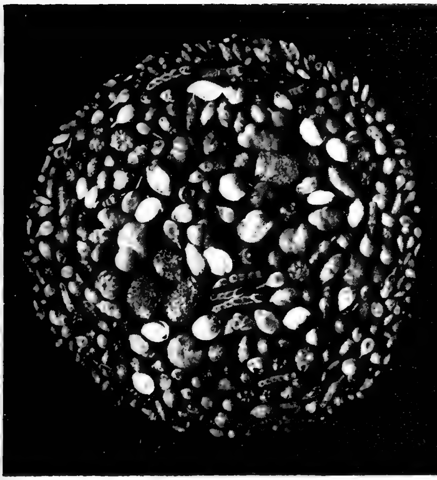


Fig. 10.—Sample 2.
Sound of Mull, 20 faths.

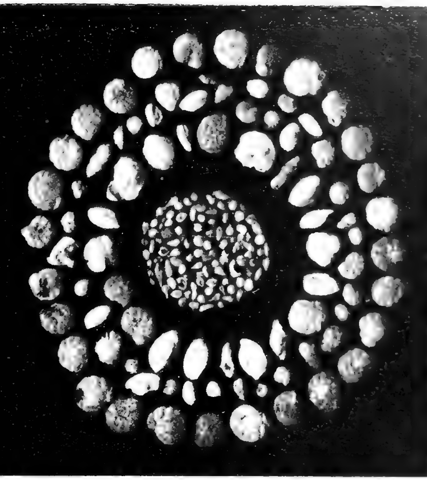


Fig. 11 —Sample 1.
Lowlandman's Bay, 5 faths.

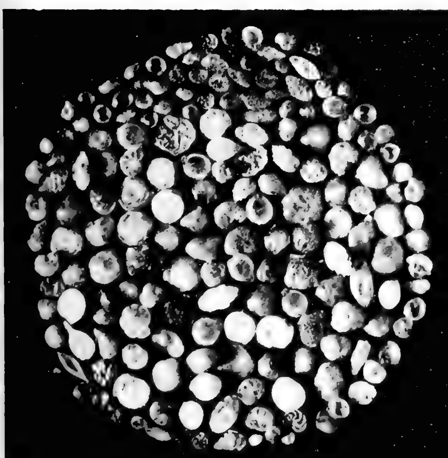


Fig. 12.—Sample 3.
Off Ardnamurchan,
20 faths.
(Fine material.)

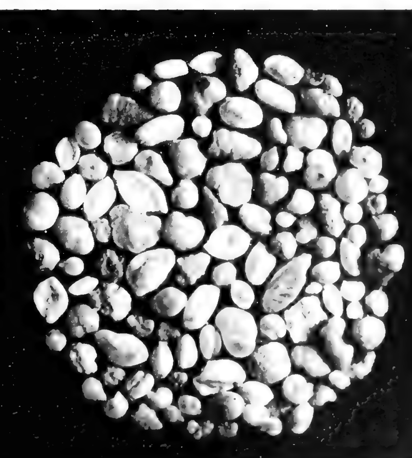


Fig. 13.—Sample 3.
Off Ardnamurchan,
20 faths.
(Coarse material.)

[Photo. by A. E. Smith

Sample 3.—Off Ardnamurchan, 20 fms., shell-bank.

2,300 c.c. of brown shell and coral débris. 1,300 c.c. passed the 1/10 sieve and were examined. 128 species.

Coarsest siftings rich in gigantic specimens. Noteworthy species *Gypsina vesicularis, Polymorphina compressa* (see fig. 13).

Finer siftings rich in small arenaceous forms, notably *Ammodiscus incertus, Trochammina rotaliformis, Haplophragmium moniliforme* and (?) *findens* (see fig. 12).

A large series of *Lagena*, many very rare forms. Among the coarsest siftings were gigantic specimens of *Pulvinulina repanda* and fistulose specimens of *Polymorphina*.

Sample 4.—Loch Sunart, 12 fms.

A solid lump of light grey sandy mud mixed with fragments of mollusca, weight $3\frac{1}{2}$ lbs., bulk 1,000 c.c. Bulk after first washing 525 c.c., residuum after final washing 348 c.c. Species c. 100.

Predominant forms *Bulimina marginata* and *B. aculeata*. A great range of *Nonionina* (especially *umbilicatula*) and of *Lagena*. Many *Nodosaria*, especially *N. scalaris*. Fine typical Lagenidæ, especially *Bulimina squaemerigera*.

The following is the list of 259 species* of Foraminifera found in the above described four samples by Mr. Heron-Allen and Mr. Earland.

	1	2	3	4
Nubecularia lucifuga, Defr.			?	
Biloculina bulloides, d'Orb.		1	1	
,, depressa, d'Orb.		f	vr	r
,, elongata, d'Orb.		c	r	r
,, ringens, Lam., sp.	1	1		
Spiroloculina acutimargo, Brady			vr	
,, excavata, d'Orb.	1	vr	f	vr
,, planulata, Lam., sp.	1	vr	vr	vr
,, tenuis, Czjzek		f	1	f

*NOTE.—It must be borne in mind that the following list is a purely preliminary and provisional one. It has been compiled from the notes made during the first examination of the material from Stations I-IV, and is intended merely to serve as an indication of the general character of the dredgings. There are several species recorded which are new to Great Britain, and several, the affinities and specific determination of which are given subject to revision and correction when the whole of the samples have been examined and compared. H-A. and E.

	1	2	3	4
Miliolina agglutinans, d'Orb., sp.		f		
,, Auberiana, d'Orb., sp.	vr		vr	
,, bicornis, Walk. and J., sp.	F	vr	f	r
,, Bosciana, d'Orb., sp.				f
,, circularis, Born., sp.	r	r	f	
,, contorta, d'Orb., sp.	r			
,, Ferrussaccii, d'Orb.		vr		
,, laevigata, d'Orb., sp.	f	vr		
,, oblonga, Mont., sp.		f	f	vr
,, pulchella, d'Orb., sp.	vr		?	vr
,, rotunda, d'Orb., sp.			1	
,, seminuda, Reuss, sp.			1	
,, seminulum, Linn., sp.	c	f	r	f
,, sclerotica, Karrer	c			
,, subrotunda, Mont., sp.	r	vr	vr	
,, tricarinata, d'Orb.	1	vr		vr
,, trigonula, Lam., sp.		vr	vr	vc
,, vulgaris, d'Orb.		r		f
Massilina secans, d'Orb., sp.	vr			
Ophthalmidium carinatum, Balk. and Wr.			vr	
Planispirina celata, Costa, sp.		f		
,, sphaera, d'Orb., sp.		vr		
Cornuspira carinata, Costa		vr		
,, foliacea, Phil.				vr
,, involvens, Rss.		1	vr	
,, Selseyensis, Heron-Allen and Earland			1	
Bathysiphon argenteus, H.-A. and E.				1
Saccamina sphaerica, M. Sars			1	
Jaculella acuta, Brady		1		
,, obtusa, Br.	fgt		fgts	
Hyperammina friabilis, Br.		1		
Reophax difflugiformis, Br.				vr
,, findens, Park., sp.			vr	
,, fusiformis, Will., sp.				1
,, moniliforme, Sidd.			vr	
,, scorpiurus, Mont.			vr	
,, Scottii, Chaster				1
Haplophragmium Canariense, d'Orb., sp.		1	c	vr
,, globigeriniforme, Park. and J., sp.			c	r
,, glomeratum, Br.		vc	vr	vr
,, pseudospirale, Will., sp.	1	f	vr	vr
Crithionina mamilla, Goes.			vr	
Ammodiscus charoides, Jones and Park., sp.		vc	1	
,, gordialis, J. and P., sp.		vr	f	
,, incertus, d'Orb., sp.			c	
Trochammina inflata, var. macrescens, Br.				vr
,, ochracea, Will., sp.			f	r
,, plicata, Terquem., sp.			f	
,, Robertsoni, Br.		vc	vr	1
,, rotaliformis, Wright		1	vr	
,, squamata, J. and P.	vr		vr	vr
Textularia agglutinans, d'Orb.			c	f
,, conica, d'Orb.		r	c	vr
,, gramen, d'Orb.	f	vc	vc	r
,, turris, d'Orb.		1	1	
Verneuilina polystropha, Rss., sp.	c	f		f
,, pygmaea, Egger, sp.				1

	1	2	3	4
Spiroplecta fusca, Earland			1	
,, Wrightii, Silvestri			r	vr
Gaudryina filiformis, Berthelin				vr
,, rudis, Wright			c	
Valvulina conica, P. and J.				1
Clavulina obscura, Chaster	vr			
Bulimina aculeata, d'Orb.	vr	vvc	r	vc
,, echinata d'Orb.	vr			r
,, elegans, d'Orb.	c	vr		vc
,, ,, var. exilis, Br.				vr
,, elegantissima, d'Orb.	vr			c
,, elongata, d'Orb.				vc
,, fusiformis, Will.	vr	f	vr	c
,, marginata, d'Orb.	c	vvc	c	vvc
,, pupoides, d'Orb.	f	vr	r	c
,, squamigera, d'Orb.	vr			vc
,, subteres, Br.	vr			f
Virgulina Schreibersiana, Cz.	vr	vr		c
Bolivina aenariensis, Costa, sp.		f		f
,, Beyrichi, Rss.				f
,, ,, var. alata, Seg.				1
,, difformis, Will., sp.	vr		f	vr
,, dilatata, Rss.	vr	f	vr	f
,, inflata, H.-A. and E.	vr			f
,, gramen, d'Orb., sp.				r
,, laevigata, Will., sp.		1		vr
,, nobilis, Hantken		f		f
,, plicata, d'Orb.	f	r	f	c
,, porrecta, Br		f		
,, punctata, d'Orb.	vr	f	f	c
,, textilarioides, Rss.				f
,, tortuosa, Br.				vr
,, variabilis, Will., sp.				c
Cassidulina Bradyii, Norman				f
,, crassa, d'Orb.	vr	f	f	c
,, laevigata, d'Orb.		vr	f	r
,, nitidula, Chaster, sp.			1	vr
,, subglobosa, Br.	f	c	c	r
Lagena acuta, Rss., sp.		f	vr	c
,, ,, var. two spines				vr
,, acuticosta, Rss.				vr
,, annectens, Burrows and Holland				r
,, apiculata, Rss.				f
,, aspera, Rss.				1
,, auriculata, Br.				1
,, bicarinata, Terq., sp.			vr	vr
,, botelliformis, Br.				vr
,, Chasteri, Millett		1		
,, clathrata, Br.				vr
,, clavata, d'Orb., sp.	r	f		f
,, costata, Will., sp.		vr	c	vr
,, falcata, Chaster				vr
,, fasciata, Egger, sp.	vc	vr	f	c
,, ,, trigonal				c
,, ,, pedunculate variety			1	1
,, fimbriata, Br.				vr
,, globosa, Mont., sp.	vr	r	f	c

	1	2	3	4
Lagena gracillima, Seg., sp.	r	f	r	vr
„ gracilis, Will.		vr		f
„ hexagona, Will., sp.	c	l		f
„ hispida, Rss.		vr		l
„ laevigata, Rss., sp.	vc	c	r	vc
„ „ trigonal				f
„ „ coarsely perforate variety				vr
„ laevis, Mont., sp.	r	r		c
„ „ curved variety				vr
„ „ var. distoma, Silv.		l		
„ lagenoides, Will., sp.	l			vr
„ „ var. tenuistriata, Br.				vr
„ lineata, Will., sp.	r			vr
„ lucida, Will.	f	r	vr	c
„ „ trigonal		vr		
„ Lyellii, Seg., sp.	l	c	l	f
„ Malcomsonii, Wright				vr
„ marginata, Walker and Boys, sp.	f	vr	vc	r
„ „ without keel				vr
„ „ var. inaequilateralis, Wr.			l	l
„ „ var. semimarginata, Reuss				vr
„ marginato-perforata, Seg.				f
„ Orbignyana, Seg.	c	f	c	c
„ ovum., Ehrenberg, sp.				l
„ ornata, Will.			l	vr
„ quadrata, Will., sp.			vr	
„ Rizzae, Seg., sp.				vr
„ reticulata, Macgill., sp.	r			vr
„ Schlichti, Silvestri				f
„ semilineata, Wright	f	l		
„ semistriata, Will.				c
„ spumosa, Millett			l	
„ squamosa, Mont., sp.	c	vr		r
„ Stewartii, Wright				vr
„ striata, W. and B., sp.	r	c	vr	c
„ sulcata, W. and B., sp.	f	vr	l	r
„ Williamsoni, Alcock, sp.	c	vr	l	f
„ „ Sideb., M.S.				vr
Nodosaria calomorpha, Rss.				vr
„ communis, d'Orb.	vr	c	l	f
„ filiformis, d'Orb.		r	l	r
„ laevigata, d'Orb.		vr		
„ mucronata, Neugeb.				vr
„ proxima, Silv.				f
„ pyrula, d'Orb.	vr	f	l	f
„ raphanistrum, Linn., sp.				vr
„ Roemeriana, Neug.		vr		
„ scalaris, Batsch., sp.	vr	c		vvc
„ „ var. separans, Br.				vr
„ vertebralis, Batsch., sp.		vr		
Lingulina bicarinata, Sideb.				vr
„ biloculi, Wright				vr
„ carinata, d'Orb.				vr
Frondicularia spathulata, Br.				vr
Marginulina costata, Batsch., sp.			l	
„ glabra, d'Orb.				l
Vaginulina legumen, Linn., sp.			l	l

	1	2	3	4
Cristellaria acutauricularis, Fich. and Moll., sp.				vr
,, convergens, Born.				r
,, crepidula, F. and M., sp.		vr	vr	vr
,, cultrata, Montf., sp.		r		vr
,, gibba, d'Orb.			l	vr
,, rotulata, Lam., sp.	l	f	l	r
,, ,, angular variety				vr
Polymorphina communis, d'Orb.				vr
,, compressa, d'Orb.		l	vr	vr
,, concava, Will.			vr	
,, gibba, d'Orb.	l		l	
,, lactea, W. and J., sp.			l	vr
,, oblonga, Will.			vr	l
,, rotundata, Born., sp.			f	
,, sororia, Rss.		vr	vr	vr
Uvigerina angulosa, Will.	r	vr	vr	f
,, canariensis, d'Orb.		l		
Sagrina nodosa, Parker & Jones		f		
Globigerina bulloides, d'Orb.	r		vr	vr
,, rubra, d'Orb.		vr		vr
Spirillina margaritifera, Will.		l	vr	
,, obconica var. carinata, Halk.			vr	
,, vivipara, Ehr.			c	
Patellina corrugata, Will.		vr	f	r
,, ,, oval variety			vr	
Discorbina Chasteri., H.-A. and E.		l	l	vr
,, globularis, d'Orb., sp.	r	f	vc	vr
,, mamilla, Will., sp.	f		vr	c
,, Mediterranensis, d'Orb., sp.	vr			vr
,, Millettii, Wright	vr		vr	
,, nitida, Will., sp.			f	vr
,, obtusa, d'Orb., sp.	f		vr	vr
,, Peruviana, d'Orb., sp.				f
,, planorbis, d'Orb., sp.	c		vr	c
,, polyrraphes, Rss., sp.	l			vr
,, Praegeri, H.-A. and E.	vr	vr	f	f
,, rosacea, d'Orb., sp.	f	vr	r	c
,, turbo, d'Orb., sp.	f			
,, Vilardeboeana, d'Orb., sp.				vr
,, Wrightii, Br.				vr
Planorbulina Mediterranensis, d'Orb.	r		c	r
Truncatulina Haidingerii, d'Orb., sp.		l		
,, lobatula, W. and J., sp.	c	r	vc	vr
,, refulgens, Montf.	vr		r	
,, Ungeriana, d'Orb., sp.			l	vr
,, variabilis, d'Orb., sp.	r		r	
Pulvinulina auricula, F. and M., sp.			vr	l
,, elegans, d'Orb.			f	
,, haliotidea, H.-A. and E.	vr		r	vr
,, Karsteni, Rss., sp.				c
,, oblonga, Will.	l			
,, punctulata, d'Orb., sp.			vr	
,, repanda, F. and M., sp.			f	
Rotalia Beccarii, Linn., sp.	vvc	c	vr	f
,, orbicularis, d'Orb., sp.			l	c
,, perlucida, H.-A. and E.				f
Gypsina inhaerens, Schul., sp.			f	vr
,, vesicularis, P. and J., sp.			r	

	1	2	3	4
Nonionina asterizans, F. and M., sp.	f	vr		c
" depressula, W. and J., sp.	c	c	r	r
" pauperata, B. and W.				vr
" scapha, F. and M., sp.....................		l		vr
" turgida, Will., sp	vr	c		vc
" umbilicatula, Mont., sp.		f	f	o
Polystomella arctica, P. and J.			vr	
" crispa, Linn., sp.	f	vr	vr	f
" decipiens, Costa.		f	vr	
" macella, F. and M., sp.	vr		vr	r
" striato-punctata, F. and M., sp. ...	vc	vr	vr	f
" striato-punctata, var. Selseyensis, H.-A. and E.				f
Operculina ammonoides, Gron., sp.	l	f		f

Fish and Plankton.

One of the points to which, as usual, we paid particular attention was the minute floating life, or plankton, of the sea, and especially any evidence of its relation to the presence or absence of useful fishes.

Some observations we made on the abundance of the large Copepod *Calanus finmarchicus* (see fig. 14), near Tober-

Fig. 14.—Copepod Plankton consisting wholly of *Calanus finmarchicus.*

mory, Mull, at an early period of the cruise—and which were much discussed on board—led to the following letter being sent to " Nature "* :—

* *Nature* for July 17th, 1913, p. 504 ; " Mackerel and Calanus."

"We all believe that most of our common food-fishes at some stage of life feed upon plankton, but those who have looked into sea-fisheries questions know that there is a great want of actual observations connecting the occurrence of some planktonic organism in quantity with the presence of a particular fish. Consequently the following record may be of interest to both marine biologists and fisheries experts.

"We are out on a scientific fisheries cruise, and in addition to members of my own family, two well-known naturalists, Professor Newstead and Mr. Alfred O. Walker, are with us on the yacht, and we have just had what we all regard as a satisfactory demonstration of the connection between a large shoal of mackerel and the occurrence of *Calanus finmarchicus* in unusual quantity.

"On arriving in this bay last night we found that the local boats had been catching abundance of mackerel close to. We bought some for supper (good fish for a halfpenny each), and on dissection found that the stomachs of all of them were crammed full of fresh-looking Calanus (the individual Copepods being for the most part distinct and perfect), along with a few immature Nyctiphanes and larval Decapods. Professor Newstead and my daughter then noticed, while fishing over the side of the yacht, about 8 p.m., that the gulls in the bay were feeding in groups around patches of agitated water evidently caused by shoals of fish. On rowing out to these we saw distinctly the mackerel, large and small, darting about in great numbers in the clear water, and we also noticed every here and there on the smooth surface of the water—it was a beautifully calm evening—innumerable small whirls or circular marks which, on looking closely, I found to be caused by large Copepoda close to the surface.

"About twenty years ago I sent a note to 'Nature,' from the yacht 'Argo,' in regard to large Copepoda (I think it was *Anomalocera* on that occasion, and the locality was further north,

off Skye), splashing on the surface so as to give the appearance of fine rain; and this present occurrence at once reminded me of the former occasion, but here the Copepod was *Calanus finmarchicus* of large size and in extraordinary abundance. They could be clearly seen with the eye on leaning over the side of the boat, a small glass collecting jar dipped at random into the water brought out twenty to thirty specimens at each dip, and a coarse grit-gauze tow-net of about 30 cm. in diameter caught about 20 cubic centimetres of the Copepoda in five minutes. The mackerel were obviously darting about, occasionally leaping to the surface (which gave the gulls their opportunity) where the whirls, caused by the Copepoda, were thickest, and an examination of the stomach-contents of the fish on the yacht afterwards showed us that the amount in one mackerel was about the same quantity as that caught by the tow-net in five minutes. Professor Newstead and I have made a count of 8 c.c. of the tow-net gathering, and estimate that it contains about 2,400 specimens of Calanus. This would give about 6,000 Copepods in the stomach of an average mackerel, or in a five minutes' haul of the tow-net, on this occasion.

"It may be added that these mackerel were evidently not being nourished in accordance with the views of Pütter, and were clearly able to fill their stomachs from the plankton around them.—W. A. Herdman. S.Y. 'Runa,' Tobermory, Mull, July 12th."

This had the happy result of causing several naturalists to write to me privately stating that they had on occasions in the past had a similar, but perhaps less striking experience; and the following letter to "Nature," from Mr. G. E. Bullen, formerly of the Plymouth Marine Laboratory, appeared in the issue of July 24th (p. 531):—

"Referring to Professor Herdman's interesting observations upon the above ('Nature,' July 17th), I may perhaps mention that the mackerel-drifters, when fishing upon the usual grounds

around Scilly and in the Bristol Channel, are largely influenced in their selection of a suitable position by the finding of so-called 'yellow water.' This condition of the sea in the area under consideration arises from the presence of vast shoals of Calanoids—e.g., *Calanus finmarchicus*, *Pseudocalanus elongatus*, &c.—which impart a yellowish tint to the surface of the water. The sporadic distribution of such Copepods, moreover, is often somewhat remarkable; the fishermen state that it is possible at times to observe the entire extent of a 'splat' of 'yellow water.' The presence of mackerel is generally to be expected in water of this character, but heavy catches are not invariably made in it.—G. E. BULLEN. The Hertfordshire Museum, St. Albans."

The following letter to "Nature,"* written at Tobermory some weeks later, records the conclusion of the matter, so far as our summer observations went:—

"On getting back to Tobermory on Saturday, we found the plankton to be in marked contrast to its condition four weeks ago (see 'Nature,' p. 504). The vast swarm of Calanoids has gone, and there are now no signs of mackerel feeding in the bay. In fact, the change has been noticeable for some days in the seas outside, and we have not been getting lately the large plankton catches that were usual in the latter half of July. On July 14th a haul of the large surface tow-net, in the open sea off Ardnamurchan, gave such a huge catch of Calanus (about 1,000 c.c.) that we promptly took a second similar haul, and had it cooked as a sort of potted 'shrimp' confection for tea (sampled by ten persons, including the crew, who were much interested to try this new edible 'fish'); while on August 11th a haul of the same net, taken at the same spot, gave only a small catch of some 15 c.c., containing very few Calanoids, along with the usual scanty summer zoo-plankton.

* *Nature*, August 21st, 1913, p. 636.

I have not yet seen any statistics of the mackerel fishery, but should not be surprised if this proves to be an exceptionally good year in this neighbourhood, especially in July.

"I have only just received 'Nature' for the last few weeks, and am glad to read Mr. G. E. Bullen's further remarks (p. 531) upon swarms of Calanoids and the fisheries. His excellent work—along with that of Dr. Allen—on the connection

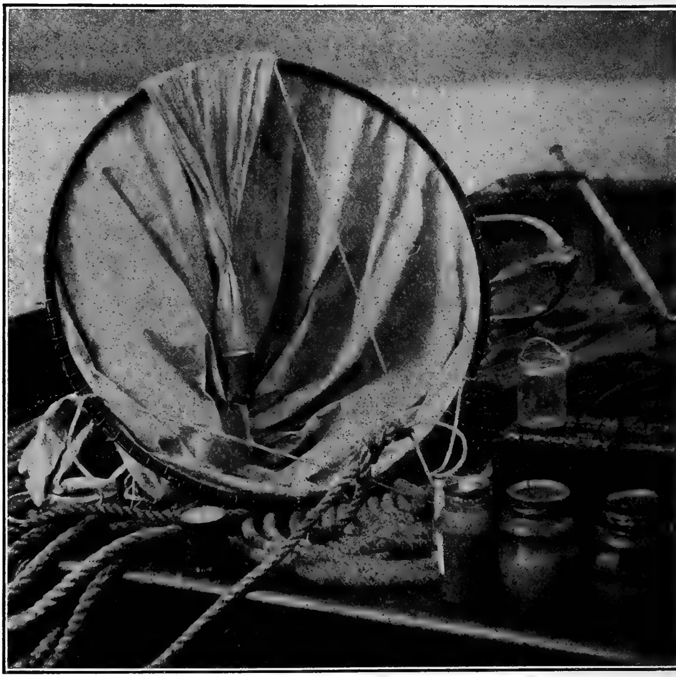


FIG. 15.—Large Nansen net and Plankton Gatherings.

between mackerel and Calanus and sunshine in the English Channel, some years ago, is valued as the type of observational and statistical work that is required for the investigation of many fishery problems.—W. A. HERDMAN. S.Y. 'Runa,' off Island of Eigg, August 12th."

Figure 15 shows the large "Nansen" tow-net used in this work, and the three collecting jars to the right show very large hauls of Copepod zoo-plankton, consisting almost wholly of *Calanus finmarchicus*, and amounting to 1,700 c.c., 1,000 c.c. and 900 c.c. respectively. The largest of these hauls has been calculated to contain at least half-a-million individuals.

THE SEA-PENS.

Amongst the bottom-living animals dredged from the "Runa" this year were all the three British Pennatulida or "Sea-pens"—viz., *Pennatula phosphorea*, *Virgularia mirabilis* and *Funiculina quadrangularis*, and this gave us the opportunity of watching the phosphorescence of the first and last of these, which are certainly amongst the most brilliantly luminous of marine animals.

We dredged *Funiculina quadrangularis* (fig. 16) in quantity in the Firth of Lorn, and then a couple of weeks later we found both Funiculina and Pennatula in the entrance to Loch Sunart, opposite Tobermory. As a result the following letter was sent to "Nature"* :—

"Professor Newstead and I have had two of the few British Pennatulida—*Pennatula phosphorea* and *Funiculina quadrangularis*—'phosphorescing' to-day before our eyes, so it may be worth recording the impressions while they are fresh. *Pennatula phosphorea*, as its name indicates, has long been known to emit light, and, writing from memory, I think Sir Wyville Thomson, in his 'Depths of the Sea,' refers to the 'lilac phosphorescence of Pavonaria' (=Funiculina). Professor Newstead and I have just seen the colour and distribution of the light very clearly in a makeshift dark room (the lazarette of the yacht), and also on the deck at midnight. In Funiculina the distribution of the luminosity is very curious and quite different from that of Pennatula. There are many distinct

* *Nature* for August 7th, 1913, p. 582 "Phosphorescence of Pennatulida."

sparkles over the polype-bearing part of the colony (corresponding, no doubt, to the individual polypes), but the long, bare lower part of the stem, 9 in. to a foot in length, when gently stroked in the dark glows with a continuous sheet of light of (it seems to me) a pale green colour which flickers or pulsates like a lambent flame. The light on this bare part of the colony is certainly more intense than that of the polypes, and is the most brilliant 'phosphorescence' I have seen in any marine animal. I have not seen Pyrosoma alive, but I imagine from the descriptions it may be even more brilliant than Funiculina.

"In Pennatula, on the other hand, the light appears to be restricted to the polypes. I have not been able to excite any luminosity in the stem portion of the colony, but the illumination of the polypes is very general and beautiful—more general and more lasting than the sparkles that the polypes give in Funiculina.

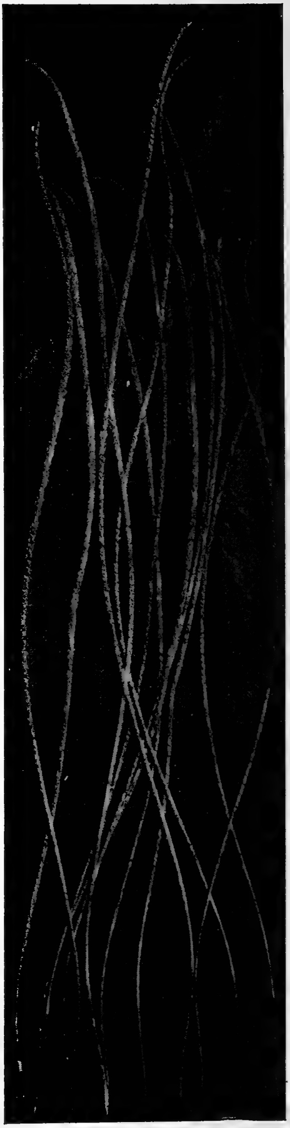


Fig. 16.—
Funiculina quadrangularis
[From a photograph.

"Professor Hickson, in a letter just received, asks me, if possible, to observe phosphorescence of the other British Pennatulid, *Virgularia mirabilis*. I have not yet succeeded in dredging Virgularia here, but it ought to be found in these waters, and probably when examined alive in the dark will show some degree of phosphorescence like its two relations referred to above.

"We have been able to get detailed colour notes of the living Funiculina, and some photographs of polypes extended to nearly an inch in length, which we hope may be useful.— W. A. HERDMAN. S.Y. 'RUNA,' Loch Sunart, N.B., July 26th."

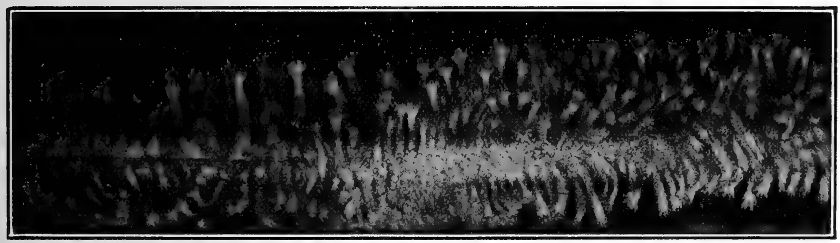


FIG. 17.—Polypes of *Funiculina quadrangularis*, expanded in Sea-water. [Photo. by Prof. R. Newstead.

Figure 16 shows the elongated cane-like colonies of Funiculina. Figure 17 is from a photograph, taken by Professor Newstead of the expanded polypes of Funiculina, as seen in a glass tube filled with sea-water; and fig. 18 shows similarly a photograph of some fine specimens of Pennatula, fully expanded in a jar of sea-water. Curiously enough when we did find Virgularia it showed no phosphorescence whatever when treated in the same way as small colonies of Funiculina which were dredged at the same time. My answer then to Professor Hickson's question is—that *Virgularia mirabilis* of our seas is not luminous.

The Hebridean Green Syntethys (*Diazona violacea*).

It will be remembered that in last year's report we described a rare and interesting compound Ascidian colony which is bright green when alive and becomes of a beautiful violet mauve tint when preserved in alcohol. I am probably correct in saying that until last year only two specimens of

Fig. 18.—*Pennatula phosphorea*, alive in a jar of sea-water : natural size. [Photo. by Prof. R. Newstead.

this rare animal from the Hebrides were known to science, the first one found by Prof. Edward Forbes off the Croulin Islands in 1850, and a second dredged by the late Duke of Argyll off the North of Mull in 1884. We got one good colony in the summer of 1912 off Barra Head, in the open Atlantic, and some small fragments further north, in the Minch. This year

I determined to make a thorough search all around the Croulin Islands, the original locality; and after some disappointing hauls, on mud, round the south and east, we came upon a shell-bank (no doubt Forbes's spot) lying to the north at a depth of 20 to 30 fathoms and there, as the result of several days' dredging, we collected over 30 fine colonies and some fragments—all green when alive and all violet now when preserved in alcohol.

This abundance of fresh material enabled us on the yacht to make some observations on the living animal (see fig. 19)

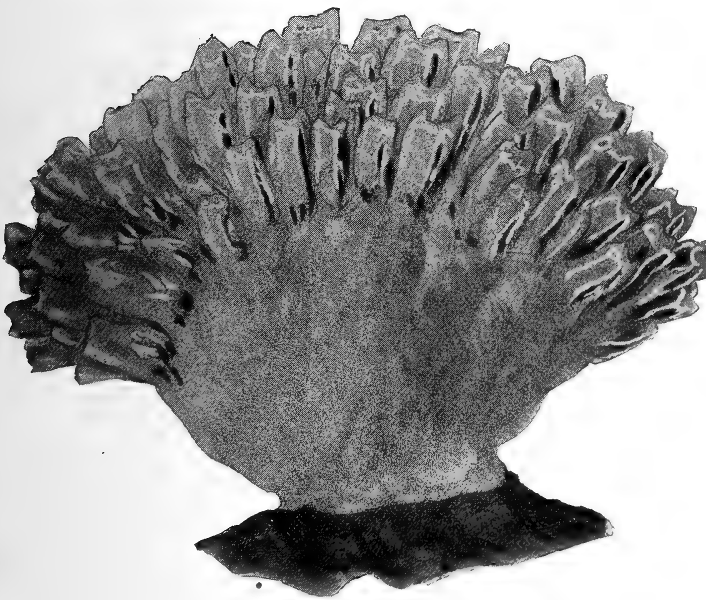


FIG. 19.—*Diazona violacea*, when alive, the "Syntethys" of Forbes.

and its curious changes of colour. It is a pale translucent green when first taken from the sea, and then becomes of a much more vivid and opaque green, then a darker blue-green, and finally, after living for a few days in the bright sunlight of a shallow basin on deck, becomes, round its edges, of a dull

slate-blue, not unlike "Stephen's blue-black" ink when freshly blotted, with here and there a slight violet or purplish tint.

The new material has also enabled Dr. Alfred Holt to carry further his chemical investigation of the nature of the pigment; and he finds that, from the absorption spectrum and other characters, the pigment in the purple portion is very similar to the indigo derivative which has been obtained by Friedländer from the gastropod mollusc *Murex brandaris*. The green colour, Dr. Holt considers, may be due to varying amounts of this blue purple pigment being dissolved in a yellow oil which he finds in the unaltered central portion of the colony. Dr. Holt's work is still in progress.

Bio-Chemical Researches.

Professor B. Moore, F.R.S., has drawn up the following "Report on Bio-Chemical investigations carried on at the Port Erin Biological Station during the years 1912-13 :—

"The research work carried out has been mainly concerned with three important problems, viz. :—

"(I.) The rôle of glycogen, lecithides and fats in the reproductive organs of Echinoderms, and on the nature and properties of the basic and acidic proteins of the sperm of *Echinus esculentus*, along with direct measurements of osmotic pressure of the protamine or histone constituent.

"(II.) Seasonal variations in the alkalinity of sea-water, accompanied by determinations of the hydrogen-ion concentration, in relation to the metabolism and seasonal balance of marine organisms, plant and animal.

"(III.) Observations of the metabolism and rate of oxidation in large marine animals, chiefly crustaceans and fishes.

"These researches have involved a large amount of work by several different observers both at Port Erin and afterwards

in the Johnston Bio-Chemical Laboratory at the University, Liverpool. The list of workers includes Professor B. Moore, Mr. E. S. Edie, Mr. E. Whitley, Dr. A. Adams, Mr. W. H. Evans, Dr. E. B. R. Prideaux, Mr. G. A. Herdman and Mr. A. Webster.

"(I.) The results of the first series of researches were published in two papers in the Bio-Chemical Journal, Vol. VII., No. 2, March, 1913 ; and the conclusions from the work, which extended over a period of more than a year, may be summarised as follows :—

"(1.) Both male and female reproductive glands in Echinoderms contain large amounts of reserve metabolic products, such as glycogen, fats and lecithides.

"(2.) These reserves are only slowly used up, if at all, when the animal is deprived of food.

"(3.) In a reproductive gland richly stored with glycogen no sugar formation occurs on keeping after death, even in a period of two days, showing that no ferment such as is found in the mammalian liver can be present.

"(4.) The amount of food consumed is much greater than that required to cover the daily metabolic wants of the animal, and is largely stored in the reproductive glands during the resting period, but it has not yet been possible to trace the utilisation of this at the active reproductive season.

"(5.) The fatty constituents of the reproductive organs of the Echinoderm are highly unsaturated, and resemble in this respect the liver oils of mammals.

"The second paper of this series deals, for the first time, with the osmotic properties of the interesting class of histones (found peculiarly in reproductive organs), and shows that a definite osmotic pressure is obtained indicating a solution-aggregate with a molecular weight lying between 8,000 and 9,000. This shows that the histones lie, in molecular complexity, between other acidic proteins such as caseinogen, and the coagulable proteins present in the serum and egg-albumen.

"(II.) The second series of researches dealt with the important observation that the hydrogen-ion concentration of sea-water determining its degree of akalinity or acidity does not remain constant throughout the year, but varies with the relative activities of vegetable and animal organisms and acts as an index to these activities.

"There are two maxima of alkalinity, or minima of hydrogen-ion concentrations, corresponding (with a slight lag in time) to the two seasonal outbursts of diatoms.

"The change observed indicates a synthesis at these seasons of some tons (per acre of sea-water) of organic vegetable matter for the nutrition of the animals.

"The green plant or diatom breaks up the bi-carbonates present in sea-water, and synthetically forms organic compounds. The amount of the removal of carbon-dioxide is shown by the increase in alkalinity. A portion of green plant placed in sea-water and exposed to sunlight causes this decomposition with remarkable rapidity. The rise in alkalinity is a surprising one, and it has been shown that it has a very definite end-point, namely that the plant continues its activity up to the limit at which all bi-carbonates have been converted into normal carbonates and then ceases. At this level the alkalinity is equivalent to that of a deci-normal solution of alkaline sodium phosphate (Na_2HPO_4), and is outside the limits on the Sörensen scale of even phenol-phthalëin as an indicator.

"In the open sea the amount of vegetation is not, of course, sufficient to drive the reaction to this limit; if it were, the alkalinity would probably be sufficient to kill all the animal plankton in the water. It is noteworthy that the spring increase in alkalinity is just of the grade formerly shown by Moore, Roaf and Whitley to be most favourable to rapidity of subdivision in the initial stages of development of the eggs of Echinus.

"The variations in reaction have now, during periodical visits to Port Erin and by means of samples of water sent over to Liverpool, been followed throughout the circuit of the year. The hydrogen-ion concentration has also been carefully controlled by the electrode method by Dr. Prideaux, and the results are now being put together for publication.

"(III.) The respiratory exchanges in crustacea and fishes, which had previously been observed over short periods not exceeding 48 hours, have now been estimated over periods of several weeks, and in some cases lobsters have been kept under experimental observation for several months. This work demands a great deal of labour, both in making the daily chemical experiments, and also afterwards in calculating out the results; but the task is now nearing completion and important data will be obtained thereby as to habits of life and the daily demand for nutrition in such animals. The daily output of carbon-dioxide and uptake of oxygen have been determined, and the quantities of protein, fat, and carbohydrate in the total animal of given body-weight, at the beginning and end of the prolonged period of the experiment, have now been carefully estimated.

"The main part of the expense of the above series of investigations has been met by grants from the Trustees of the Percy-Sladen Memorial Fund, to whom a full report upon the details of the work with statement of results will be presented in due course."

Plankton Investigations at Port Erin.

The plankton work has been carried on in much the same way for the last six years, with the help of various Assistants, from the S.Y. "Runa" out at sea during the Easter and Summer vacations, and across Port Erin Bay in small boats during the rest of the year.

In all, about 400 samples have been collected from Port Erin and the neighbourhood during the year, in addition to those from other parts of the Irish Sea. A detailed account of the plankton results will be given, as usual, by Mr. Scott and myself in the Lancashire Sea Fisheries Laboratory Report.

Last year (1912) the plankton hauls in the Irish Sea were exceptionally large, some nettings in April containing as many as 36 millions of one species and 44 millions of another species of the diatom genus *Chaetoceras*, while one haul on May 30th contained over 107 millions of *Rhizosolenia shrubsolei.* In the present year (1913) the numbers generally were lower, and no exceptionally large hauls were obtained. The diatom maximum was in May and was largely composed of 3 species of *Chaetoceras* (*C. debile*, *C. sociale* and *C. teres*). The genus *Thalassiosira*, which appeared in April at Port Erin, increased to 6½ millions per haul by the middle of May and died off a month later in June.

Rhizosolenia was the chief diatom present in June and July, beginning with *R. shrubsolei* which was replaced later by *R. stolterfothi.* In the September maximum the chief diatoms were *Chaetoceras decipiens*, *C. debile* and *C. densum.*

The summer maxima of both the Copepoda and the Dinoflagellata occurred in July.

Early in July there was a great visitation of the Ctenophore *Pleurobrachia pileus* (see fig. 20) all along the Lancashire coast; and Mr. Scott found that a sample of mackerel caught on July 8th off Walney Island contained nothing but *Pleurobrachia* in the stomachs. A fortnight earlier in the same region the mackerel were feeding mainly on Copepoda, one examined having a pure gathering of *Temora*, while others had *Sagitta*, *Oikopleura* and larval decapods. It is evident that fish like herring and mackerel although they may be attracted by some special organism, like Calanus, are able to a considerable extent

to take what comes, and consequently are found feeding now upon one thing and now upon another.

At the time, early in July, when Mr. Scott was finding the sea off the Lancashire coast swarming with *Pleurobrachia* to such an extent that a 5 minutes' haul choked the tow-net, on the West Coast of Scotland, off Mull, we found the plankton almost wholly composed of Copepoda, and especially of *Calanus finmarchicus*.

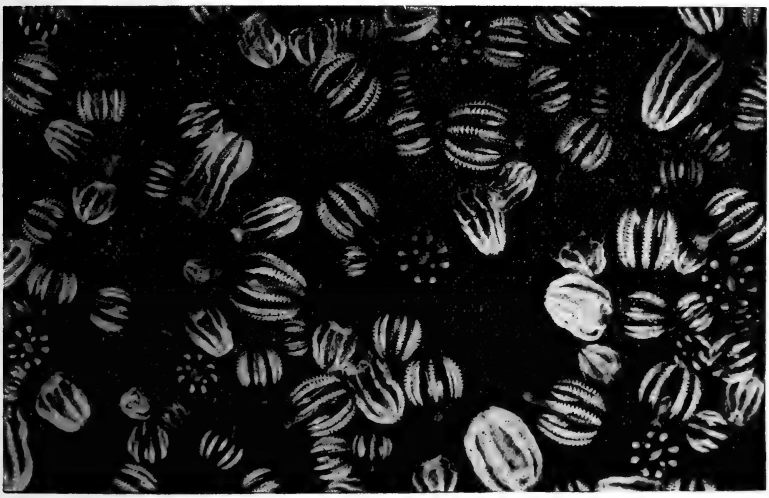


FIG. 20.—A remarkable Plankton haul of the Ctenophore, *Pleurobrachia pileus*: natural size. [Photo. by Mr. A. Scott.

THE UTILITY OF PLANKTON INVESTIGATION.

It must be obvious to those who read these Annual Reports that a good deal of our work at Port Erin of late years has consisted in series of observations, and the collection of samples, for the purpose of determining the nature and distribution of the plankton at different localities, depths and seasons. Conse-

quently, it may be of interest that I should print here a few paragraphs from an article that was drawn up for last year's report on the Lancashire Sea Fisheries scientific investigations for the purpose of showing what was known of the connection between plankton distribution and the occurrence of fisheries.

Many of the older naturalists worked at marine plankton qualitatively, and even connected the prevalence of certain organisms with the prosperity of sea-fisheries; but modern instruments and methods of precision, such as might be expected to prove quantitatively the influence of variations in the type and amount of plankton, at different seasons and depths, upon the movements and abundance of fishes, have only been employed of recent years, and it is still too early to expect much in the way of demonstrated result. However, some data have been obtained which are full of promise for the future.

Many commercial fishes feed upon plankton during at least some portion of their life. The Loch Fyne herrings are frequently, at the time of a fishery, found to have their stomachs filled with *Nyctiphanes*, *Euchaeta* or *Calanus*. In some parts of the Hebridean seas the herrings have their stomachs filled with the Pteropod *Limacina retroversa*, and other oceanic organisms which may be carried in swarms into our coastal waters. Many other similar cases could be quoted, and are known to biologists.

Then as to demersal fish—young plaice, after their metamorphosis, feed chiefly on Copepoda, while in younger stages the larval plaice feeds upon Diatoms. We have found at Port Erin the post-larval plaice with its stomach shining through of a golden-brown colour from the Diatoms with which it was filled, and we have watched in a shallow pond the metamorphosed small plaice darting backwards and forwards pursuing, catching and devouring the individual Copepoda. Then again it has been shown that these Copepoda in their turn feed on

Diatoms, Dinoflagellates and Protozoa. So practically all the main constituents of the plankton are concerned in the nourishment of either young or adult fishes. On the Lancashire coast we find the young plaice which are just appearing in the inshore nurseries have their stomachs filled with pelagic larval annelids.

The Pollan (*Coregonus pollan*) of Lough Neagh, in Ireland, has been shown to be on some occasions filled up with *Mysis relicta,* and at other times to be feeding solely on Cladocera; and there is reason to believe that the movements of the fish, which are extensive and periodic, can be definitely related to the presence and nature of the plankton.

Dr. Hjort has shown a correspondence between the distribution of the plankton-feeding whales (such as the Greenland whale) and the most abundant swarms of plankton at particular seasons. Professor G. O. Sars and others, in tracing shoals of herring and cod in the North and West of Norway, have distinguished between the "feeding" migrations and the spawning migrations, and the feeding migrations depend upon the plankton.

It seems, probable that, in order to get an adequate quantity of planktonic food the fish, in most cases, must seek out and capture the Copepoda, for example, just as fish on occasions have been seen to do. In other words, the fish must go where the plankton is abundant, and must in its migrations follow the movements of shoals of plankton. It is the very poverty of the plankton in some sea areas, insisted on by Pütter, Lohmann and others, which makes it necessary for plankton-eating fish to move about in search of more abundant supplies.

This association of shoals of fish with abundance of plankton is in agreement with many observations that have been made by naturalists in the past. It is well known that in coastal waters favourite line-fishing localities are usually where strong tides run through narrow channels or over rocks and

banks, and these are just the places where of recent years it has been found that plankton is also most abundant.

Any naturalist cruising on the West of Scotland (and no doubt in any other region where there are strong tides) could scarcely fail to notice the way in which the gulls and other sea-birds congregate where the currents run most strongly and where there are swirls in the water, indicating rocks or an uneven bottom, and resulting vertical movements of the water. These sea-birds are found to be feeding upon young fish, and the fish are there because the plankton is unusually abundant.

A definite connection seems to have been established on the coast of Cornwall, by Allen and Bullen, between the results of the mackerel fishery and the occurrence of *Calanus* in the plankton. There is some evidence that on the West coast of Scotland there is a similar connection between herring shoals and abundance of *Calanus*.* The matter is well worthy of further investigation.

Many groups of the plankton, and especially the zoo-plankton, it is now known quite definitely, are distributed in swarms—notwithstanding various assertions to the contrary. In our coastal seas at least, where the fisheries we are interested in take place, the plankton is *not* uniformly distributed. Various localities and depths are characterised at different seasons by particular assemblages of plankton, and it is reasonable to believe, in view of the facts given above as to the association of fish and plankton, that these variations in the distribution must have a marked effect upon the presence and abundance of at least such fish as herring and mackerel, and also of the shoals of post-larval young of many valuable demersal fishes.

There is a method about the detailed distribution of the plankton that convinces one it must depend upon laws or factors

* See also the connection between Mackerel and *Calanus* given in this report at p. 52.

which can probably be ascertained, and thus lead to the possibility of correlation with prediction within limits.

Observations made by Nansen and Helland-Hansen, in 1909, showed that variations in the Atlantic currents have an important influence upon the physical conditions not only of the Norwegian sea, but also of the atmosphere and the climate on land, and so upon the development of both marine and terrestrial life. It was shown that variations in the temperature of the Atlantic water were followed by corresponding variations in the winter climate of Norway, in the fisheries of the North Sea and at Lofoten. There was, moreover, a remarkable correspondence between the annual variations in the Atlantic surface temperatures in May and the variations in the harvests and even in the growth of the pine forests in Norway. As the Prince of Monaco puts it :—" Le plankton est, en effet, un véritable ' témoin ' des phénomènes physiques qui s'accomplissent dans l'océan." And M. Cligny, of the Station Aquicole at Boulogne, has shown that the enormous banks of herrings which have been trawled from the bottom at several localities round the British Islands of late years, cannot be correlated with any peculiarity of bottom nor depth, nor even with temperature and salinity, but are on the borders where the Atlantic and the coastal waters meet, and where the oceanic water has brought in an unusual supply of plankton—such as the Pteropod *Limacina retroversa*. The Swedish and Danish hydrographers have similarly established that there is a direct connection between the Bohuslan herring fishery and the invasion of the Skaggerrak by salter water from the North Sea meeting and pushing back the less salt Baltic water.

That different currents or bodies of water in the sea differ very notably in their plankton is well known to biologists who have tested the matter. For example, in crossing the Atlantic to Canada one can tell to a nicety, even by means of a small silk net attached to a bath tap on a passenger steamer, when the

ship has entered the Labrador current. The catch of plankton is suddenly increased enormously, and consists of an entirely different assemblage of organisms ; and this abundant plankton is probably definitely related to the great fisheries on the Newfoundland Banks.

Observations in the Irish Sea and on the West of Scotland have shown that the plankton at a locality may fluctuate, both in amount and essential nature, from year to year ; and although a definite relation between these fluctuations and the variations in the distribution and catches of fish has not yet been established, it is reasonably probable that a fuller and more detailed knowledge of both will enable a correlation to be demonstrated.

It is clear then that there are definite relations between fishes and plankton organisms, and that it seems possible with fuller data to correlate some of the movements of fish with the distribution of plankton. There is thus a reasonable probability that an increased knowledge of the minute life of the sea may be directly useful in connection with the regulation of fishing industries.

Plankton investigation in relation to the fluctuations of fisheries is now being carried on throughout the seas of North-west Europe, and it has been decided by the International Council for the organisation of the work that the nets to be used for this purpose should be :—

(1) Medium Apstein, gauze No. 20 [180 meshes per inch] diameter of opening 16 cm.

(2) Nansen net, gauze No. 3 [55 meshes per inch] diameter of opening 50 cm.

And these special nets, we at Port Erin, like other investigating bodies, will certainly have to use in the future for our statistical observations.

One of the resolutions of the International Council in connection with this work is, naturally, that :—

"With a view to determining the relation of plankton and fishes, simultaneous examination should be made of the stomach contents of pelagic fish and the plankton in the surrounding waters."

In pursuance of this policy we have started at Port Erin the investigation of the plankton and fish occurring in association with the summer Port St. Mary herring fishery, which is being carried out by Mr. Bygrave (see above, p. 37); and it was with the same object in view that we examined into the relations of the mackerel and Calanus around Tobermory during the cruise of the "Runa" (see p. 52).

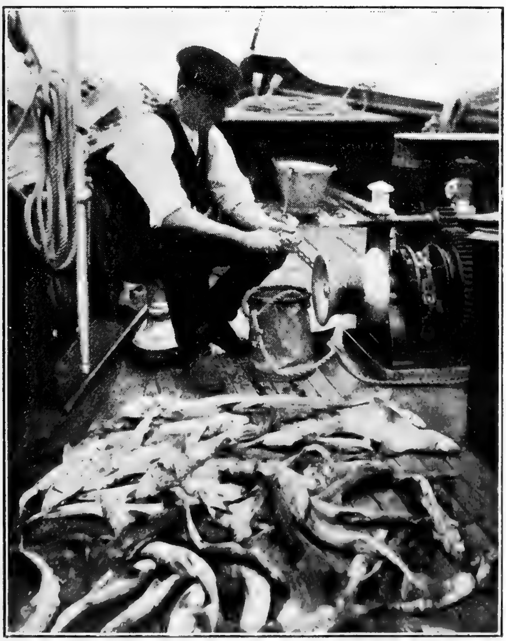
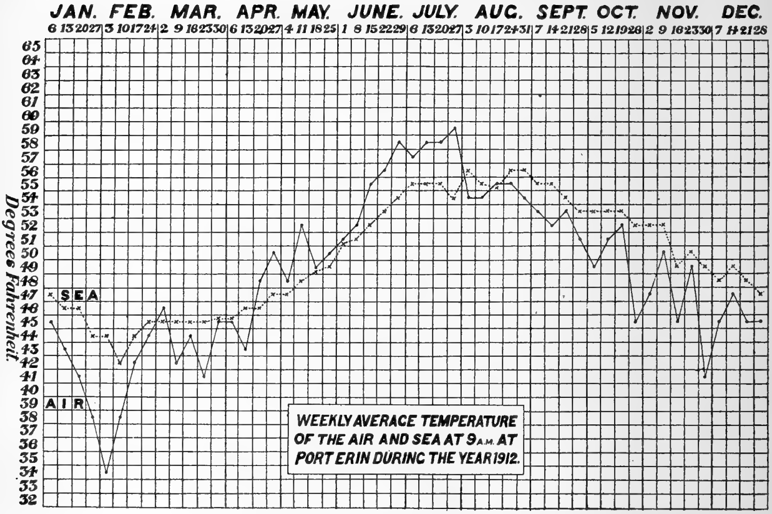
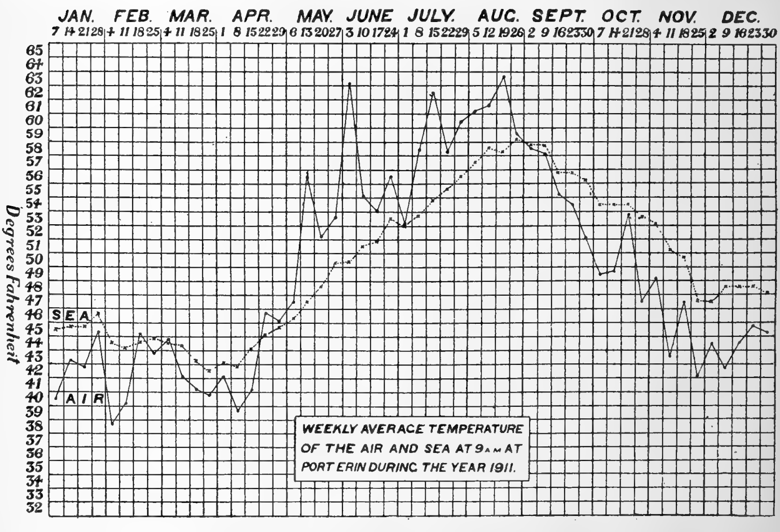


FIG 21.—Over 50 Dog-fishes caught in an hour with hook and line from the "Runa," in Loch Sunart.


JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC.
Degrees Fahrenheit.
SEA
AIR
WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN DURING THE YEAR 1912.


JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC.
Degrees Fahrenheit
SEA
AIR
WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9 A.M. AT PORT ERIN DURING THE YEAR 1911.

The diagram of sea and air temperatures for 1913, compiled by Mr. Chadwick from his daily records, is not yet completed; but those for the two preceding years, 1911 and 1912, are inserted here to show the general similarity of the two curves along with a few points of divergence, and to demonstrate again the manner in which the temperature of the sea lags behind that of the air in both winter and summer.

Judging from the time of appearance and the maxima of most of the plankton groups, 1912 was an unusually early year. The Diatoms made their appearance in quantity earlier, and the maxima of the Dinoflagellates and the Copepods were about a month earlier than in 1911. Although 1911 had an unusually hot and dry summer, it was not until late in April that the temperature of the sea rose above 45° F., while in 1912 the sea-temperature was 45° or over from the end of February onwards.

The annexed charts show the contrast between the two years very clearly.

L.M.B.C. Memoirs.

Since our last report was published, Memoir XXI on Eupagurus, the Hermit Crab, by Mr. H. G. Jackson, M.Sc., has been issued to the public. Miss E. L. Gleave, M.Sc., has nearly completed her Memoir on Doris, the Sea-lemon; Mr. Chadwick is engaged on a Memoir on the Echinoderm Larvæ of Port Erin; and still others are in preparation.

The following shows a list of the Memoirs already published or arranged for:

I. Ascidia, W. A. Herdman, 60 pp., 5 Pls.

II. Cardium, J. Johnstone, 92 pp., 7 Pls.

III. Echinus, H. C. Chadwick, 36 pp., 5 Pls.

IV. Codium, R. J. H. Gibson and H. Auld, 3 Pls.

V. Alcyonium, S. J. Hickson, 30 pp., 3 Pls.
VI. Lepeophtheirus and Lernæa, A. Scott, 5 Pls.
VII. Lineus, R. C. Punnett, 40 pp., 4 Pls.
VIII. Plaice, F. J. Cole and J. Johnstone, 11 Pls.
IX. Chondrus, O. V. Darbishire, 50 pp., 7 Pls.
X. Patella, J. R. A. Davis and H. J. Fleure, 4 Pls.
XI. Arenicola, J. H. Ashworth, 126 pp., 8 Pls.
XII. Gammarus, M. Cussans, 55 pp., 4 Pls.
XIII. Anurida, A. D. Imms, 107 pp., 8 Pls.
XIV. Ligia, C. G. Hewitt, 45 pp., 4 Pls.
XV. Antedon, H. C. Chadwick, 55 pp., 7 Pls.
XVI. Cancer, J. Pearson, 217 pp., 13 Pls.
XVII. Pecten, W. J. Dakin, 144 pp., 9 Pls.
XVIII. Eledone, A. Isgrove, 113 pp., 10 Pls.
XIX. Polychaet Larvæ, F. H. Gravely, 87 pp., 4 Pls.
XX. Buccinum, W. J. Dakin, 123 pp., 8 Pls.
XXI. Eupagurus, H. G. Jackson.
Echinoderm Larvæ, H. C. Chadwick.
Doris, E. L. Gleave.
Sagitta, S. T. Burfield.
Actinia, J. A. Clubb.
Zostera, R. Robbins.
Halichondria and Sycon, A. Dendy.
Oyster, W. A. Herdman and J. T. Jenkins.
Sabellaria, A. T. Watson.
Ostracod (Cythere), A. Scott.
Asterias, H. C. Chadwick.
Botrylloides, W. A. Herdman.

In addition to these, it is hoped that other Memoirs will be arranged for, on suitable types, such as *Pontobdella*, a Cestode, a Nematode and a Pycnogonid.

We append to this Report :—

(A) The usual Statement as to the constitution of the L.M.B.C., and the Laboratory Regulations—with Memoranda for the use of students;

(B) The Hon. Treasurer's Report, List of Subscribers, and Balance Sheet for the year.

Fig. 22.—Two Nestlings of Red-breasted Merganser first day after hatching. From nest on island near Bunessan, Loch Scriddain, Mull.

[Photo. by Prof. R. Newstead.

Appendix A.

THE LIVERPOOL MARINE BIOLOGY COMMITTEE (1913).

His Excellency the Right Hon. Lord Raglan, Lieut.-Governor of the Isle of Man.

Rt. Hon. Sir John Brunner, Bart.

Prof. R. J. Harvey Gibson, M.A., F.L.S., Liverpool.

Mr. W. J. Halls, Liverpool.

Prof. W. A. Herdman, D.Sc., F.R.S., F.L.S., Liverpool. Chairman of the L.M.B.C., and Hon. Director of the Biological Station.

Mr. P. M. C. Kermode, Ramsey, Isle of Man.

Prof. Benjamin Moore, F.R.S., Liverpool.

Sir Charles Petrie, Liverpool.

Mr. E. Thompson, Liverpool, Hon. Treasurer.

Mr. A. O. Walker, F.L.S., J.P., formerly of Chester.

Mr. Arnold T. Watson, F.L.S., Sheffield.

Curator of the Station—Mr. H. C. Chadwick, A.L.S.

Assistant—Mr. T. N. Cregeen.

CONSTITUTION OF THE L.M.B.C.

(Established March, 1885.)

I.—The Object of the L.M.B.C. is to investigate the Marine Fauna and Flora (and any related subjects such as submarine geology and the physical condition of the water) of Liverpool Bay and the neighbouring parts of the Irish Sea and, if practicable, to establish and maintain a Biological Station on some convenient part of the coast.

II.—The Committee shall consist of not more than 12 and not less than 10 members, of whom 3 shall form a quorum ; and a meeting shall be called at least once a year for the purpose of arranging the Annual Report, passing the Treasurer's accounts, and transacting any other necessary business.

III.—During the year the Affairs of the Committee shall be conducted by an Hon. Director, who shall be Chairman of the Committee, and an Hon. Treasurer, both of whom shall be appointed at the Annual Meeting, and shall be eligible for re-election.

IV.—Any Vacancies on the Committee, caused by death or resignation, shall be filled by the election at the Annual Meeting of those who, by their work on the Marine Biology of the district, or by their sympathy with science, seem best fitted to help in advancing the work of the Committee.

V.—The Expenses of the investigations, of the publication of results, and of the maintenance of the Biological Station shall be defrayed by the Committee, who, for this purpose, shall ask for subscriptions or donations from the public, and for grants from scientific funds.

VI.—The Biological Station shall be used primarily for the Exploring work of the Committee, and the Specimens collected shall, so far as is necessary, be placed in the first

instance at the disposal of the members of the Committee and other specialists who are reporting upon groups of organisms; work places in the Biological Station may, however, be rented by the week, month, or year to students and others, and duplicate specimens which, in the opinion of the Committee, can be spared may be sold to museums and laboratories.

A quiet corner on the North shore of Port Erin Bay.

LIVERPOOL MARINE BIOLOGICAL STATION
AT
PORT ERIN.

General Regulations.

I.—This Biological Station is under the control of the Liverpool Marine Biology Committee, the executive of which consists of the Hon. Director (Prof. Herdman, F.R.S.) and the Hon. Treasurer (Mr. E. Thompson).

II.—In the absence of the Director, and of all other members of the Committee, the Station is under the temporary control of the Resident Curator (Mr. H. C. Chadwick), who will keep the keys, and will decide, in the event of any difficulty, which places are to be occupied by workers, and how the tanks, boats, collecting apparatus, &c., are to be employed.

III.—The Resident Curator will be ready at all reasonable hours and within reasonable limits to give assistance to workers at the Station, and to do his best to supply them with material for their investigations.

IV.—Visitors will be admitted, on payment of a small specified charge, at fixed hours, to see the Aquarium and Museum adjoining the Station. Occasional public lectures are given in the Institution by members of the Committee.

V.—Those who are entitled to work in the Station, when there is room, and after formal application to the Director, are :—(1) Annual Subscribers of one guinea or upwards to the funds (each guinea subscribed entitling to the use of a work place for three weeks), and (2) others who are not annual subscribers, but who pay the Treasurer 10s. per week for the accommodation and privileges. Institutions, such as Univer-

sities and Museums, may become subscribers in order that a work place may be at the disposal of their students or staff for a certain period annually; a subscription of two guineas will secure a work place for six weeks in the year, a subscription of five guineas for four months, and a subscription of £10 for the whole year.

VI.—Each worker is entitled to a work place opposite a window in the Laboratory, and may make use of the microscopes and other apparatus, and of the boats, dredges, tow-nets, &c., so far as is compatible with the claims of other workers, and with the routine work of the Station.

VII.—Each worker will be allowed to use one pint of methylated spirit per week free. Any further amount required must be paid for. All dishes, jars, bottles, tubes, and other glass may be used freely, but must not be taken away from the Laboratory. Workers desirous of making, preserving, or taking away collections of marine animals and plants, can make special arrangements with the Director or Treasurer in regard to bottles and preservatives. Although workers in the Station are free to make their own collections at Port Erin, it must be clearly understood that (as in other Biological Stations) no specimens must be taken for such purposes from the Laboratory stock, nor from the Aquarium tanks, nor from the steam-boat dredging expeditions, as these specimens are the property of the Committee. The specimens in the Laboratory stock are preserved for sale, the animals in the tanks are for the instruction of visitors to the Aquarium, and as all the expenses of steam-boat dredging expeditions are defrayed by the Committee, the specimens obtained on these occasions must be retained by the Committee (*a*) for the use of the specialists working at the Fauna of Liverpool Bay, (*b*) to replenish the tanks, and (*c*) to add to the stock of duplicate animals for sale from the Laboratory.

VIII.—Each worker at the Station is expected to lay a paper on some of his results—or at least a short report upon his work—before the Biological Society of Liverpool during the current or the following session.

IX.—All subscriptions, payments, and other communications relating to finance, should be sent to the Hon. Treasurer. Applications for permission to work at the Station, or for specimens, or any communications in regard to the scientific work should be made to Professor Herdman, F.R.S., University, Liverpool.

Cairn-a-burgh More from natural arch on Cairn-a-burgh Beg, Treshnish Isles.
[Photo. by W. A. H.

Memoranda for Students and Others working at the Port Erin Biological Station.

Post-graduate students and others carrying on research will be accommodated in the small work-rooms of the ground floor laboratory and in those on the upper floor of the new research wing. Some of these little rooms have space for two persons who are working together, but researchers who require more space for apparatus or experiments will, so far as the accommodation allows, be given rooms to themselves.

Undergraduate students working as members of a class will occupy the large laboratory on the upper floor or the front museum gallery, and it is very desirable that these students should keep to regular hours of work. As a rule, it is not expected that they should devote the whole of each day to work in the laboratory, but should rather, when tides are suitable, spend a portion at least of either forenoon or afternoon on the sea-shore collecting and observing.

Occasional collecting expeditions are arranged under guidance either on the sea-shore or out at sea, and all undergraduate workers should make a point of taking part in these.

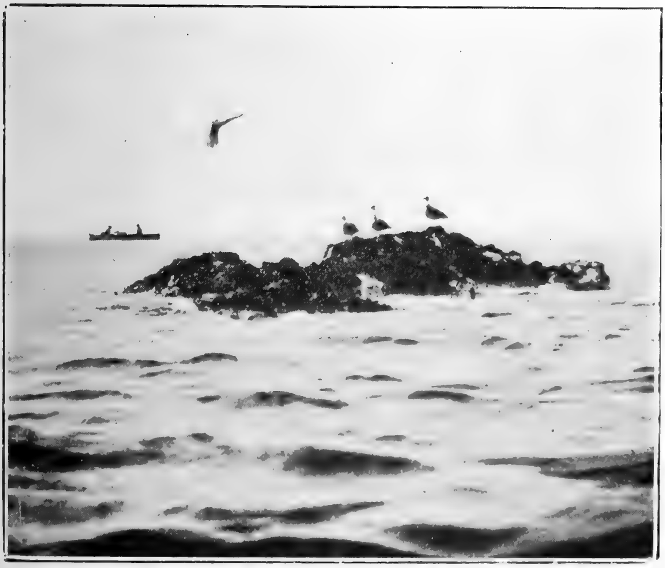
It is desirable that students should also occasionally take plankton gatherings in the bay for examination in the living state, and boats are provided for this purpose at the expense of the Biological Station to a reasonable extent. Students desiring to obtain a boat for such a purpose must apply to the Curator at the Laboratory for a boat voucher. Boats for pleasure trips are not supplied by the Biological Station, but must be provided by those who desire them at their own expense.

Students requiring any apparatus, glass-ware or chemicals from the store-room must apply to the Curator. Although the Committee keep a few microscopes at the Biological Station,

these are mainly required for the use of the staff or for general demonstration purposes. Students are therefore strongly advised, especially during University vacations, not to rely upon being able to obtain a suitable microscope, but ought if possible to bring their own instruments.

Students are advised to provide themselves upon arrival with the " Guide to the Aquarium " (price 3d.), and should each also buy a copy of the set of Local Maps (price 2d.) upon which to insert their faunistic records and other notes.

Occasional evening meetings in the Biological Station for lecture and demonstration purposes will be arranged from time to time. Apart from these, it is generally not advisable that students should come back to work in the laboratory in the evening ; and in all cases all lights will be put out and doors locked at 10 p.m. When the institution is closed, the key can be obtained, by those who have a valid reason for entering the building, only on personal application to Mr. Chadwick, the Curator, at 3, Rowany Terrace.



Sea-birds on the Skear at the mouth of Port Erin bay.

Appendix B.

HON. TREASURER'S STATEMENT.

In the following pages the Balance Sheet and list of subscriptions and donations are shown. Year by year the expenses at Port Erin increase owing to the greater number of students that work at the Biological Station, and also to the increased amount of work that is done there. There is, therefore, a greater necessity for increased support, either by annual subscriptions or by special donations in order to enable the Committee to open up further fields of useful work and research.

There is a useful library at the Port Erin Biological Station for use of students and other workers, and any donations, either of books or money, will be most appreciated.

We have again this year received a Grant from the Board of Agriculture for research work, some of which has been spent in Lobster Rearing. Full particulars of this are given in the report.

Edwin Thompson,
Hon. Treasurer.

25, Sefton Drive,
Liverpool. *December 20th,* 1913.

SUBSCRIBERS.

	£	s.	d.
Browne, Edward T., B.A., Anglefield, Berkhamsted, Herts.	1	1	0
Brunner, Mond & Co., Northwich...	1	1	0
Brunner, Rt. Hon. Sir John, Bart., Silverlands, Chertsey	5	0	0
Brunner, J. F. L., M.P., 23, Weatherley Gardens, London, S.W.	2	2	0
Brunner, Roscoe, Belmont Hall, Northwich ...	1	1	0
Caton, Dr., 78, Rodney-street, Liverpool	1	1	0
Clubb, Dr. J. A., Public Museums, Liverpool ...	0	10	6
Cole, Prof., University College, Reading	1	1	0
Crellin, John C., J.P., Andreas, I. of Man... ...	0	10	0
Dale, Sir Alfred, University, Liverpool	1	1	0
Dixon-Nuttall, F. R., J.P., F.R.M.S., Prescot ...	2	2	0
Gibson, Prof. R. J. Harvey, The University, Liverpool	1	1	0
Graveley, F. H., Indian Museum, Calcutta ...	0	10	6
Halls, W. J., 35, Lord-street, Liverpool	1	1	0
Herdman, Prof., F.R.S., University, Liverpool ...	2	2	0
Hewitt, David B., J.P., Northwich	1	1	0
Hickson, Prof., F.R.S., University, Manchester ...	1	1	0
Hill, Prof. J. P., University College, London ...	1	1	0
Holland, Walter, Carnatic Hall, Mossley Hill ...	1	1	0
Holt, Dr. Alfred, Dowsefield, Allerton	1	0	0
Holt, Mrs., Sudley, Mossley Hill, Liverpool ...	2	2	0
Holt, P. H., Croxteth-gate, Sefton-park, Liverpool	1	1	0
Isle of Man Natural History Society	2	2	0
Jarmay, Gustav, Hartford, Cheshire	1	1	0
Livingston, Charles, 16, Brunswick-st., Liverpool	1	1	0
Manchester Microscopical Society...	1	1	0
Meade-King, R. R., Tower Buildings, Liverpool...	0	10	0
Mond, R., Sevenoaks, Kent...	5	0	0
Monks, F. W., Warrington...	2	2	0
Mottram, V. H., The University, Liverpool ...	1	1	0
Forward	£43	10	0

	£	s.	d.
Forward... ...	43	10	0
Muspratt, Dr. E. K., Seaforth Hall, Liverpool ...	5	0	0
O'Connell, Dr. J. H., Dunloe, Heathfield-road, Liverpool	1	1	0
Petrie, Sir Charles, Devonshire-road, Liverpool ...	1	1	0
Rathbone, Mrs. Theo., Backwood, Neston... ...	1	1	0
Rathbone, Miss May, Northumberland-street, London	1	1	0
Rathbone, Mrs., Green Bank, Allerton, Liverpool	2	0	0
Roberts, Mrs. Isaac, Thomery, S. et M., France ...	1	1	1
Robinson, Miss M. E., Holmfield, Aigburth, L'pool	1	0	0
Smith, A. T., 43, Castle-street, Liverpool... ...	1	1	0
Tate, Sir W. H., Woolton, Liverpool	2	2	0
Thompson, Edwin, 25, Sefton Drive, Liverpool ...	1	1	0
Thornely, Miss, Nunclose, Grassendale	0	10	0
Thornely, Miss L. R., Nunclose, Grassendale ...	2	2	0
Toll, J. M., 49, Newsham-drive, Liverpool ...	1	1	0
Walker, Alfred O., Ulcombe Place, Maidstone ...	3	3	0
Ward, Dr. Francis, 20, Park Road, Ipswich ...	2	2	0
Watson, A. T., Tapton-crescent Road, Sheffield ...	1	1	0
Whitley, Edward, Oxford	2	2	0
Weiss, Prof. F. E., University, Manchester ...	1	1	0
Yates, Harry, 75, Shudehill, Manchester	1	1	0
	£75	2	1
Deduct Subscriptions still unpaid *less* old Subscriptions received	4	4	0
	£70	18	1
Add Subscriptions for 1914	5	0	0
	£75	18	1

SUBSCRIPTIONS FOR THE HIRE OF "WORK-TABLES."

	£	s.	d.
Victoria University, Manchester	£10	0	0
University, Liverpool	10	0	0
University, Birmingham	10	0	0
University College, London	2	2	0
Bedford College for Women, London	2	2	0
University College, Reading	2	2	0
	£36	6	0
Deduct Subscriptions still unpaid *less* 1912 Subscriptions paid	4	4	0
	£32	2	0

DONATIONS.

	£	s.	d.
Bullen, Mrs. R. A.	£4	4	0
Stebbing, Rev. T. R. R.	1	1	0
	£5	5	0

THE LIVERPOOL MARINE BIOLOGY COMMITTEE.

Dr. In Account with EDWIN THOMPSON, Hon. Treasurer. **Cr.**

1913.	£	s.	d.
To Balance due Hon. Treasurer, December, 1912 ...	12	4	6
,, Printing and Stationery	27	6	6
,, Boat Hire	6	11	3
,, Books and Apparatus at Port Erin Biological Station	23	10	8
,, Postage, Carriage, &c.	5	13	3
,, Expenses for Collecting Specimens	5	18	4
,, Salary—Share of Curator's	85	0	0
,, ,, ,, Assistant's	26	15	6
,, Sundries	7	6	3
,, Balance in Hand, December, 1913	12	8	11
	£212	15	2

Endowed Invested Fund:—
British Workman's Public House Co. 90 Shares £1 each fully paid.

EDWIN THOMPSON,
Hon. Treasurer.

Audited and found correct,
COOK & LEATHER,
Chartered Accountants.

Liverpool, *December 20th, 1913.*

1913.	£	s.	d.
By Subscriptions and Donations received	81	3	1
,, Amount received from Universities for hire of "Work Tables"	32	2	0
,, Laboratory Fees	25	0	0
,, Admissions to Aquarium, Share of	9	1	1
,, Interest on British Association (1896) Fund ...	37	13	4
,, Interest on Investment	2	15	11
,, Sale of Guides	13	9	0
,, ,, Post Cards	0	14	8
,, ,, Annual Reports	0	17	6
,, ,, Specimens, Bottles, &c,	4	13	2
,, Bank Interest	5	5	5
	£212	15	2

	£	s.	d.
Memoir Fund—Balance, December, 1912	132	13	2
By Sale of Memoirs	38	9	1
	£171	2	3
Cost of Eupagurus Memoir	41	0	9
	£130	1	6

	£	s.	d.
Extension Fund:—Balance, as at December, 1912	£37	4	9

Grant from Board of Agriculture and Fisheries—	£	s.	d.
Balance of Grant for 1912	£75	0	0
Grant for 1913	100	0	0
	£175	0	0

REPORT ON THE INVESTIGATIONS CARRIED ON DURING 1913 IN CONNECTION WITH THE LANCASHIRE SEA-FISHERIES LABORATORY AT THE UNIVERSITY OF LIVERPOOL, AND THE SEA-FISH HATCHERY AT PIEL, NEAR BARROW.

EDITED BY

PROFESSOR W. A. HERDMAN, F.R.S.,
Honorary Director of the Scientific Work.

(With plates, charts and text figures.)

CONTENTS.

INTRODUCTION.

As in the case of last year's Report, Dr. Johnstone and Mr. Riddell deal with various sections of their work under the Scheme of Fishery investigation sanctioned by the Development Commission and the Board of Agriculture and Fisheries. The remaining articles in this Report deal with cognate matters which seem to be worthy of exposition and record, such as fish-hatching, plankton investigation, the diseases of fish, the nutrition of marine animals, and the condition of mussel beds in relation to sewage.

Scheme of Fisheries Investigation.

It is understood that the Development Commissioners are at present considering the details of a comprehensive scheme for fisheries investigation throughout British Seas which has been drawn up by the three Government Departments concerned. Until, however, this scheme has been approved, the system of interim grants from the Development Fund has been continued, and our scientific work is being carried on for another year on the same lines as in previous years, and with the same grant-in-aid. It is hoped that when a more permanent scheme is adopted by the Development Commission, provision will be made to meet an increased expenditure on the necessary investigations in the Irish Sea Fisheries area.

On Scientific grounds the proposal for an amalgamation of the investigations in the Cumberland and the Lancashire districts is a sound one which ought to be encouraged by the Authorities concerned. It means practically an extension of the Lancashire scheme of operations into Cumberland waters—an object highly desirable in itself, beneficial both to Cumberland and

Lancashire, and one which would seem to have a good claim for a grant-in-aid of expenses from the Development Fund.

Amongst other new investigations which it is proposed the Scientific Staff should undertake, with the sanction of the Committee, during the coming year, may be mentioned:—

The proposed investigation of the spawning of the sole in our district, in May.

The extension of the "Herring races" investigation to Manx waters, in June.

Further examination of the Welsh Mussel Fisheries with the view to their improvement by artificial operations.

The Work at Piel.

The Sea-Fish hatching has been carried on by Mr. A. Scott on the same lines as in former years. Over one million plaice, and twelve millions of flounders were hatched and set free. It may be of interest to add that in the same season about eight millions of plaice were set free from the Port Erin hatchery in the Isle of Man.

The usual Classes for Fishermen were carried on by Dr. Johnstone and Capt. Thornber on the same lines as in former years, and with the usual success. A very considerable proportion of the men were successful in obtaining their Board of Trade certificates. The Nature Study evening classes were also restarted by Dr. Johnstone and Mr. Scott for the Education Committee of Barrow, with the concurrence of the Scientific Sub-Committee.

The usual Reports on the hatching and on the classes, etc., at Piel are given. Mr Scott also has an article on mackerel investigations. This is a new line of research. Mr. Scott has gone out with the local boats, and has made

observations on the mackerel, their sizes, sexual condition, and food in relation to the plankton. Mr. Scott gives an interesting description, with figures, of the food of the mackerel. Some observations bearing on the food of the mackerel in Scottish waters at the same season will be found in another paper by Mr. Riddell and myself further on in the Report.

Mr. Scott continues his former work on the distribution of fish eggs. He has examined the plankton collected by the "James Fletcher" on the northern offshore grounds between the Isle of Man and the coasts of Lancashire and Cumberland, and also the plankton collected throughout the year in Port Erin Bay by the staff of the Biological Station. His paper contains notes on the range of distribution, with periods of occurrence of the eggs of various species of fish.

Plankton Work.

The other plankton investigations have been carried on as in previous years. Along with Mr. Scott and Miss H. M. Lewis, I now submit the seventh part of our work on the intensive study of the plankton of the Irish Sea round the South end of the Isle of Man. I consider it important to complete, if possible, ten years' observations before winding up the work and drawing conclusions. Along with Mr. Riddell, I contribute a brief Report on the summer plankton of the West coast of Scotland for comparison with the plankton simultaneously collected on the Lancashire coast by our Fisheries steamer, and in Port Erin Bay.

The plankton hauls made from the "James Fletcher" in 1913 have been worked up by Mr. Riddell. Tables of the occurrence and relative abundance of all organisms

identified, with notes on the species, are given in the Report in continuation of the similar tables published in former years.

Parasites and Diseases of Fishes.

Dr. Johnstone continues his work on diseases of fishes. He records the occurrence of, and describes several interesting fish parasites. Various abnormal and pathological conditions in edible fishes are described, including reports on several specimens of fishes condemned by Inspectors. This work is mainly of theoretical importance, but has practical and administrative bearings. Market Inspectors do not, as yet, know enough of the pathology of fishes to help them in their work. Valuable fish have sometimes been condemned, although the abnormal appearances on which the condemnation was based did not necessarily render the fish unsuitable for human food. On the other hand, it might be dangerous to health to allow obviously diseased fish to be sold as human food so long as the precise nature of the disease is unknown. From this point of view Dr. Johnstone's investigations of these various diseased conditions is very valuable.

Fishery Statistical Investigations.

Dr. Johnstone continues his detailed work on measurements of plaice:—(1) the measurements of the lengths of the plaice captured on board the "James Fletcher," and to a smaller extent on board some of the Bailiffs' cutters; (2) the examination of the samples of plaice sent to the Liverpool University Laboratory. Neither series of records is as complete as it might be, but still they are of value. Tables giving the results of all these measurements are published in this Report in the

same form as during the past five years:—(1) The lengths of the plaice caught, given in centimetre groups; (2) the values of the length-weight coefficient *k*, that is, the index of the average condition of the fish, on the various grounds, and at different seasons; (3) the age, sex, and phase of sexual maturity of the plaice examined in the laboratory.

Dr. Johnstone also adds to this report a summary of the investigations of the same kind carried on during the years 1909-1913. This includes statements of the average sizes of the plaice found on:—(1) The summer fishing grounds between Blackpool and Liverpool Bar; (2) off the Estuaries of the Mersey and Dee; (3) on the shrimping grounds in the Mersey Estuary; (4) on the winter fishing grounds off the coasts of Carnarvon and Anglesey; and (5) in Luce Bay (for the years 1908-1912). Tables showing the actual numbers of fish at each centimetre of length, in each month of the year, and also the percentage of the whole catches per month and ground, at each centimetre of length, are given, and also summary statements as to the weight and length, and also the age and length, of the plaice examined.

This statement for the quinquennial period 1909-1913 has been made in order to find, if possible, any deficiencies in our methods, and any possible ways of improving our scheme of investigation. It seems to show that the measurements are useful so far as they go, but are not numerous enough. The plaice fisheries in certain parts of the district are still uninvestigated, although the inclusion of these fisheries was provided for in the scheme approved by the Development Commission. Also, we are of opinion that these measurements should be extended to all soles caught, and that the investigation of the sole spawning grounds should be made during the coming summer.

The Committee are, no doubt, aware of the proposal by the International Fisheries Bureau to impose legal size limits on plaice. It is suggested that it be made illegal to land plaice during the summer months less than 22 cms. (nearly 9 inches) long. It seems quite possible that this proposal may be adopted, and extended to the Irish Sea. A summary statement given in this Report by Dr. Johnstone will enable the Committee to forecast the result of this proposal, if adopted for our district. Applied to the summer plaice fishery between Blackpool and the Liverpool Bar, it will mean that:—

76%	of all the plaice caught in	May	must be returned to the sea,	or cannot be landed.
74	,,	June	,,	,,
70	,,	July	,,	,,
62	,,	Aug.	,,	,,
62	,,	Sept.	,,	,,
53	,,	Oct.	,,	,,

That is, these are the percentages of plaice on this ground which are smaller than 22 cms. (say, $8\frac{3}{4}$ inches). The proposal, therefore, is one which will seriously affect Lancashire inshore fishermen, and should be carefully considered in all its bearings.

Plaice-Marking Experiments.

About 1,000 plaice were marked and liberated in 1913, and the results are now reported upon by Dr. Johnstone, assisted by Mr. T. Monaghan. The results confirm those of former years, and show: (1) irregular, mainly alongshore migrations into bays and estuaries, of small plaice in winter; (2) offshore migration of plaice of 7 inches long and upwards in summer months; (3) inshore migration of these smaller plaice in the "back-

end" of the year; (4) migration to South-West, to Red Wharf Bay and vicinity, of the medium-sized plaice inhabiting waters just offshore from Blackpool to Liverpool Bar in summer; (5) spawning migration of the larger plaice to grounds between Bahama Bank and Selker Light Vessel at end of year, or South to grounds in St. George's Channel.

These results indicate that the imposition of legal size limits will differentiate in favour of steam trawlers and first-class sailing trawlers, and against the second-class trawlers. For the small plaice that may not be caught on the summer grounds by the second-class boats will migrate in the back end of the year to the grounds frequented by the steam trawlers and first-class boats. Probably they would not grow to the same extent if they remained on the shallow water grounds, and if the latter are not "thinned" by fishing. These latter are naturally overcrowded grounds.

Attention may be drawn to the Barrow Channel experiment. This illustrates the very great importance of stake-net fishing in the Lancashire inshore waters. This mode of fishing should be very carefully studied. Experimental stake nets were provided for this purpose about a year ago, but no results have been obtained yet.

Hydrographic Investigations.

These have been carried on as in 1912. The observations at sea, and the collection of the water samples have been made by Mr. Wm. Riddell; while Professor Bassett reports on the chemical analyses of the samples. Professor Bassett's report gives tables of data, and discusses the results, mainly from the point of view of the flow of water from the Atlantic into the Irish Sea, and the irregularity

of this inflow from year to year. Some charts are also given in this report which illustrate the variable distribution of Atlantic sea-temperatures from year to year. These are based on the temperature observations recorded in the Atlantic "Pilot Charts," and they show that any isotherm varies in latitude (when it crosses any particular meridian) from month to month, and also from year to year. Doubtless this monthly and annual variation in the ocean may yet be utilised in the attempt to forecast the temperature variation in shallow seas, such as our Fishery District.

Investigation of the Herring.

In this first paper on the subject Mr. Riddell gives measurements of certain selected characters of the herring. The samples examined consist of about 100 herring from the coast of Wales, and 150 herring caught off the Smalls by Fleetwood and Milford steam-trawlers. The investigation was commenced because of the agitation of the last few years with regard to the new method of capturing herring by otter trawls worked from steam trawlers. It forms part of the general scheme of investigation arranged by the Board of Agriculture and Fisheries for the purpose of studying the races of herring in British Seas. Mr. Riddell gives tables, and shows that there are apparently significant differences in the characters of the Welsh and the steam-trawl caught herrings. The investigation will be extended to the Manx herring in summer.

Sea-Bottom Deposits and the Food of Fishes.

While Mr. Robert Ray was working as a post-graduate researcher last session in the Liverpool Laboratory, I set him to obtain and examine a series of samples of sea-

bottoms collected by the oyster dredge at various localities between Morecambe Bay and Bahama Light Vessels and the coasts of Lancashire and Cumberland. Mr. Ray's report deals also with the examination of the contents of the alimentary canals of the fish caught at the time on the same grounds. The geological nature of the sands, muds, &c., forming the bottom deposits are described, and the contained organisms and remains of organisms are identified. The organisms forming the food of the fishes caught are also identified, with the view of correlating these with the organisms found on the different sea-bottoms. The present report is essentially of a preliminary nature, and much further work on the subject remains to be done. We hope to continue the investigation in the future by means of Petersen's "bottom sampler."

Bacteriological Investigations.

Dr. Johnstone describes the topography of the mussel grounds in the estuary of the Ribble, and also at Portmadoc, Barmouth, and Aberdovey. He also gives the results of bacteriological analyses, and shows that there is very grave contamination in the mussels at Aberdovey and Barmouth. Similar analyses for Portmadoc and the Ribble Channel are also given. The numbers of sewage bacteria contained in badly-polluted mussels, such as those at Aberdovey, may amount to 20,000, while mussels free from contamination, such as those at Roosebeck, near Piel, give only about five or six organisms per shell-fish. Dr. Johnstone is going on with further very important work relating to the precise nature of the bacteria found in these shell-fish.

Mr. Durlacher reports on experiments in the estuaries

of the Dovey and the Mawddach in relation to the flow of sewage. He has observed the directions taken by weighted floats, and has also made determinations of the density of the water at different places in both estuaries. He shows that surface currents from the vicinity of the sewer outfalls flow mainly parallel to the shore, and in some cases directly over the mussel beds. The problem of any proper place for a cleansing pond thus becomes one of great difficulty, and it is suggested that some method of purification similar to that proposed for Conway might be employed. The experiments at Conway thus become of increased importance, as they may be applicable to other localities.

Nutrition of Marine Animals.

In view of the remarkable statements published a few years ago by Professor A. Pütter, and accepted by some biologists in this country, that marine animals, including even fishes, could be nourished by the dissolved organic carbon in sea-water, I invited Professor Benjamin Moore to conduct a bio-chemical investigation of the matter at the Port Erin Biological Station. I am glad to be able to include in this volume two very important papers by Professor Moore and others who worked with him, which seem to prove conclusively that Pütter was mistaken, that there are no such quantities of dissolved carbon in sea-water as he supposed, and that when a marine animal is kept for long periods without solid food, although it may not lose weight, it is undergoing profound changes in its constitution, and is really subsisting on its own tissues.

Amongst other minor pieces of work may be mentioned the statistical investigation bearing on the life-

history of the shrimp upon which Mr. T. Monaghan has been started. A preliminary note with table and a chart will be found in this Report. The statistics are obtained from the examination of periodic samples from the Mersey Estuary. The shrimps are all measured, and the percentages of males, berried females and non-berried females, are determined. The fecundity of the shrimp is also being studied.

Mr. H. G. Jackson gives a further note on the occurrence of larval stages of the higher Decapod Crustacea, such as crabs, shrimps, and prawns in the deeper plankton gatherings off the Isle of Man.

W. A. HERDMAN.

Fisheries Laboratory,
University of Liverpool,
April 15th, 1914.

FISH HATCHING AT PIEL.

By Andrew Scott, A.L.S.

The fish hatching operations carried on in 1913 gave results very similar to what we have had in former years. Thanks to the continued kindness of the Fishery Board for Scotland, we are enabled, year after year, to renew our stock of adult plaice from the closed area of Luce Bay. Without such a privilege it is almost certain that a sufficient number of adult plaice would not be obtained in the open area of the Irish Sea in a reasonable time. The results of the plankton investigations conducted in 1913 indicate that there were very few spawning plaice between Lancashire and the Isle of Man. Thirty-nine surface tow-nettings were taken all over the northern area of the Irish Sea between February and the middle of April. Plaice eggs were found in nineteen of the samples, but the total number only amounted to fifty-nine. When it is remembered that a single spawning female plaice may produce 200,000 eggs in the course of a couple of weeks, one naturally expects that the eggs will be fairly numerous if adults are plentiful. It also follows, if adults are scarce, that there will be few eggs floating near the surface. There can be no doubt that closed areas with an environment favourable to the life of the adult fish, and where commercial trawling is prohibited, must be of an immense value to the adjacent fishing grounds. The flounders were caught in the vicinity of Piel by the police cutter belonging to the northern division. A number of flounders were also collected by the steamer when trawling on the off-shore fishing grounds for material for use in the classes.

The adult plaice and flounders, kept in the tanks all winter, matured much earlier than in previous years. They commenced to spawn on February 25th, and two days later

the first fertilised eggs were placed in the hatching boxes for incubation. This is about three weeks earlier than in 1912, and is the earliest spawning that has taken place in our tanks.* The last eggs were collected on April 24th. The spawning was therefore completed in eight weeks. During that period one and a quarter millions of plaice eggs were collected, and thirteen and a half millions of flounder eggs. The eggs were incubated in the usual manner and the resulting fry were liberated from time to time. The adult fish were also liberated at the end of the work. The experiment of marking the adults before liberation, which had been done in 1912, was not repeated, as none were returned to us.

The following tables give the number of eggs collected, and of the fry hatched and set free on the dates specified :—

Plaice (*Pleuronectes platessa*, Linn.).

		Eggs Collected.	Fry Set Free.		
Feb.	27	... 20,000	16,000 ...	March	20
March	2	... 35,000	30,000 ...	,,	25
,,	4	... 45,000	39,000 ...	,,	,,
,,	7	... 55,000	46,500 ...	,,	31
,,	9	... 65,000	57,000 ...	,,	,,
,,	11	... 70,000	60,000 ...	,,	,,
,,	13	... 75,000	65,500 ...	April	7
,,	15	... 80,000	69,000 ...	,,	,,
,,	18	... 80,000	69,000 ...	,,	14
,,	21	... 90,000	79,000 ...	,,	,,
,,	24	... 95,000	84,000 ...	,,	21
,,	27	... 90,000	79,000 ...	,,	,,
,,	31	... 90,000	79,000 ...	,,	28
April	4	... 85,000	74,000 ...	,,	,,
,,	8	... 85,000	74,000 ...	May	5
,,	12	... 75,000	65,500 ...	,,	,,
,,	16	.. 55,000	46,500 ...	,,	14
,,	20	... 40,000	33,000 ...	,,	,,
,,	24	... 25,000	20,000 ...	,,	,,
Total Eggs		1,255,000	1,086,000	Total Fry.	

*It is curious that at the Port Erin Fish Hatchery the Plaice spawn a good deal earlier than at Piel. This year the first fertilised plaice eggs were obtained in the Port Erin pond on February 4th.—W.A.H.

FLOUNDER (*Pleuronectes flesus*, Linn.).

		Eggs Collected.	Fry Set Free.		
Feb.	27	... 250,000	221,000	... March	14
March	2	... 400,000	354,000	... ,,	,,
,,	4	... 650,000	575,000	... ,,	20
,,	7	... 700,000	600,000	... ,,	,,
,,	9	... 750,000	658,000	... ,,	25
,,	11	... 800,000	711,000	... ,,	,,
,,	13	... 850,000	757,000	... ,,	31
,,	15	... 950,000	846,000	... ,,	,,
,,	18	... 1,000,000	887,000	... April	7
,,	21	... 1,000,000	887,000	... ,,	,,
,,	24	... 1,100,000	975,000	... ,,	14
,,	27	... 1,000,000	887,000	... ,,	,,
,,	31	... 900,000	800,000	... ,,	21
April	4	... 850,000	757,000	... ,,	,,
,,	8	... 750,000	660,000	... ,,	28
,,	12	... 600,000	528,000	... ,,	,,
,,	16	... 450,000	397,000	... May	5
,,	20	... 350,000	300,000	... ,,	,,
,,	24	... 230,000	200,000	... ,,	14
	Total Eggs	13,580,000	12,000,000	Total Fry.	

Total Number of Eggs 14,835,000

Total Number of Fry 13,086,000

CLASSES, VISITORS, &c., AT PIEL.

By Andrew Scott, A.L.S.

Four classes for fishermen were held at Piel in 1913. The Education Committee of the Lancashire County Council voted the usual amount of money which enables forty-five fishermen, residing in the administrative area, to receive studentships for a fortnightly course of instruction in Elementary Marine Biology, or a combined course in Marine Biology and Navigation. They also permitted Captain E. Barker Thornber, the County Navigation Instructor, to be present for a period of six weeks. Captain Thornber gave instruction in Navigation and Seamanship to thirty-nine of the studentship holders who were qualified to sit for the Board of Trade certificates. The Education Committee of the County Borough of Southport sent four men, and the Education Committee of the County Borough of Blackpool again sent three men. Altogether, fifty-two men attended the classes and received instruction in Marine Biology. Thirty-nine of them also attended the course in Navigation. The studentship holders were divided into four classes—one of eleven men, one of thirteen, and two of fourteen each, as shown by the following lists :—

First class, held February 17th to 28th—Henry Benson, Flookburgh ; William Butler, Flookburgh ; Eardley Hadwen, Morecambe ; Peter Wilson, Morecambe ; John Woodhouse, Morecambe ; John Owen, Blackpool ; Tom Craven, Blackpool ; John Smith, Blackpool ; Richard Ball, Banks ; Thomas Howard, Southport ; Thomas Sutton, Southport ; James Wareing, Southport ; John Wright, Southport.

Second Class, held March 3rd to 14th—Arthur Ainsworth, George H. Birch, J. Brooks, John W. Cawthorne, Thomas Cowell, Harry Gawne, J. Grundy, George Hughes, James

Monaghan, Robert Perry, John Salthouse, Robert Scott, Thomas Smith, Richard Snasdell, Fleetwood.

Third Class, held March 31st to April 11th—W. Bird, L. Eastwood, R. Iddon, N. Leadbetter, H. Livesey, A. Mayson, W. Martland, J. Scott, D. Singleton, E. Tomlinson, H. Wood, C. Wood, R. Wright, T. Wright, Fleetwood.

Fourth Class, held April 14th to 25th—G. Brooks, R. Eastwood, W. Howells, L. Kelly, S. Phillips, H. Stanley, F. Stepp, M. Sumner, R. Swales, H. Symonds, R. Wright, Fleetwood.

The first class was attended by inshore fishermen, such as musselers, cocklers, shrimpers and men from second-class fishing boats. Their course of instruction dealt with general Marine Biology, similar to what has been given in former years. The second, third, and fourth classes were only open to deep-sea fishermen residing in Fleetwood. The selected men had put in the necessary sea time to enable them to present themselves for the Board of Trade examination for certificates as second hand or skipper of a fishing vessel. They were also students of the Navigation School at Fleetwood, to whom a fortnight's continuous study was of the utmost importance in finishing up their work previous to the examinations. The morning lesson, lasting two and a half hours, was devoted to instruction in Marine Zoology, having some bearing on the fish and more common invertebrates captured in the trawl net. The afternoon lesson of three hours was conducted by Captain Thornber, and a very efficient course in Navigation and Seamanship was given. The laboratory was open to the Navigation students in the evenings, and many of them took advantage of this to revise their afternoon's instruction, do chart-work, and have *viva voce* examinations by Captain Thornber on rule of the road at sea. Nineteen of the students were subsequently successful at the examinations held at Fleetwood. Four of them obtained skipper's certificates, and fifteen mate's certifi-

cates of fishing vessels. A visit of inspection of the last fishermen's class was made by Dr. Snape, Director of Education for Lancashire, Dr. Jenkins, Mr. A. Harris, H.M. Inspector of Evening Schools, and Dr. Hoffert, H.M. Divisional Inspector of Evening Schools. A new edition (the 3rd) of the syllabus of lessons for fishermen attending the classes has been recently published. It has been revised and improved, and new illustrations added. A section on Navigation has been written by Captain Thornber, which should prove useful to the students and others who wish to know something about the amount of knowledge required to obtain certificates as officers of fishing vessels.

A sub-committee of the Departmental Committee on Inshore Fisheries, which was visiting the ports and fishing stations between the Bristol Channel and the Solway Firth to take local evidence and meet the fishermen, visited the establishment on June 18th. Two of the local fishermen were called in, and various questions relating to the past and present state of the fisheries for fish and shell-fish in the neighbourhood were discussed.

Lt.-Col. John M. Semmens, V.D., of the Fisheries and Game Department of the State of Victoria, and Professor Hidemi Senō, Imperial Fisheries Institute, Tokyo, Japan, visited the establishment during the year to see the hatching apparatus and make enquiry regarding scientific investigations and instruction to fishermen.

We have again to thank the United States Fisheries Department; the Smithsonian Institution; Professor E. Ehrenbaum, of the Biological Station at Heligoland; Dr. Annandale, Superintendent of the Indian Museum; Mr. E. W. L. Holt, Scientific Adviser to the Irish Fisheries Department; and others, for further additions to the library during the year.

THE MACKEREL FISHERY OFF WALNEY IN 1913.

By Andrew Scott, A.L.S.

Mackerel were extremely abundant and widely distributed in the Irish Sea during the summer of 1913. The fish made their appearance in the area lying off Walney Island about the middle of June, and were evidently fairly numerous until about the end of the first week in September. The mackerel came quite close to the land on this occasion. Many were caught by line in Barrow Channel, in the vicinity of the ferry pier at Piel, and a few were taken in the stake nets on Roosebeck Scars. Although the fish apparently left the area off Walney early in September, they continued to be caught off Blackpool until late in October. In all probability the abundance of mackerel was largely due to a remarkably extensive invasion of the ctenophore *Pleurobrachia*, along with numerous small examples of *Beröe*. The visitation of the ctenophora began early in July and lasted for nearly a month. The swarm reached its maximum about the 10th, and then gradually diminished in numbers. The water of the open sea and in Barrow Channel was so densely populated for a time with *Pleurobrachia*, that an ordinary coarse tow-net was quickly filled when towed behind a boat. Great numbers were stranded on the shore as the tide receded, which gave it the appearance of being covered with small glass marbles. The local fishermen, with their half-decked fishing boats, caught considerable quantities of mackerel by line during the fishery, but they were frequently prevented from reaching the fishing ground owing to too much or too little wind. Under more favourable conditions the fishery would have been very valuable, as the catches were quickly sold at about one shilling per dozen fish.

Samples of the fish were bought from time to time from the men for investigation, and on one occasion a personal visit was made to the area in the police cutter "Piel Castle."

Size and Weight of the Fish.

The size of the fish caught varied from 21 cms. to 36 cms. in length, measured from the tip of the snout to the base of the fork of the tail. Mackerel between 22 cms. and 26 cms. were abundant, but the larger sizes appeared to be comparatively scarce. The scarcity of the larger sizes may have been due to their absence in the area usually fished by the local men. It was quite noticeable during the visit to the fishing ground that boats, fishing off the south end of Walney, were catching large numbers of the smaller sizes. The fish caught off the North end of Walney Island and at the entrance to Duddon Channel were nearly all over 28 cms. in length. The local fishermen rarely went so far North, for if the wind happened to die away—a not infrequent occurrence, they would then have been outside the tidal drift into Barrow Channel. The mackerel caught in Barrow Channel and in the stake nets at Roosebeck were usually all over 30 cms. The weight of the fish increased very rapidly per centimetre, as will be seen from the table. The average weight of a 21 cms. mackerel was found to be 94 grammes. A 36 cms. mackerel weighed 484 grammes. This represents an increase in weight of 390 grammes for an increase in length of 15 cms. Fish of the same length varied considerably in weight according to the condition of the stomach. An empty fish of course weighed less than one which had been recently feeding. Two fish measuring 31 cms. weighed 290 grammes and 330 grammes respectively. The former had nothing in its stomach while the latter contained two freshly captured sand eels measuring 12 cms. in length.

Size.		Weight.	Size.		Weight.
21 cms.	..	94 grammes.	29 cms.	..	253·5 grammes.
22 ,,	..	105·4 ,,	30 ,,	..	262 ,,
23 ,,	..	120 ,,	31 ,,	..	314·5 ,,
24 ,,	..	134·65 ,,	32 ,,	..	325·7 ,,
25 ,,	..	168·7 ,,	33 ,,	..	357·8 ,,
26 ,,	..	186·15 ,,	34 ,,	..	393 ,,
27 ,,	..	198·5 ,,	35 ,,	..	449 ,,
28 ,,	..	226·3 ,,	36 ,,	..	484 ,,

Condition of the Reproductive Organs.

None of the fish under 24 cms. in length, from the area off Walney Island, had the reproductive organs developed to such an extent that the sex could be recognised by naked eye observation. The condition of maturity in the fish of 24 cms. and upwards was very irregular. There was no gradual approach to a definite spawning time. Some of the fish caught in September were no further advanced towards spawning than many of those caught at the end of June. In the sample examined on June 30th one spent female, 27 cms. long, and one male, 30 cms. long, with the sperms flowing freely were observed. The others were not more than half mature. One spent female, 35 cms. long, was found amongst the fish examined during July. The others over 24 cms. were mostly quite immature. A few were just about half mature. The mackerel examined in the first week of September were, with one exception (a spent female 31 cms. long) about half mature. The spawning period varies greatly in different places. In the Mediterranean spawning may begin as early as January, and extend into May. In the South-west of Ireland the time stated is May and June. Off Plymouth spawning takes place between the end of May and the end of July. The reproductive organs of the mackerel caught off Walney in 1913 were in quite a different condition from those examined in previous years. It has been quite a common occurrence to find them in a spent

condition in July. Only three spent female fish and one mature male were observed in 1913. The eggs were present in three tow-nettings only in 1913.

Food.

The mackerel is a migratory pelagic fish and finds its food in the water through which it swims. The food will, therefore, vary according to the changes occurring in the constituents of the plankton. An examination of the stomach contents generally gives a fair indication of the nature of the plankton in the area where the fish have been caught, especially if they have been some little time in it. As the food consists of the organisms in the water through which the fish swims, it is to be expected that the fish in one area may be feeding on quite a different kind of organism from those in another area. It is well known that sudden invasions of organisms may occur from time to time in the plankton, and may have quite a local distribution. One of the most noteworthy of these sudden invasions is the extraordinary shoals of the amphipod *Euthemisto compressa*, which make their appearance along the Yorkshire Coast occasionally in the spring, in such immense numbers that drifts of them, several inches in depth, are thrown up by the waves. The fishermen frequently remove the heaps in barrow loads to put on their gardens as manure. This amphipod is a distinctly northern form, and is usually regarded as a rare species on the British coasts. Its occurrence in such swarms so far from its true home has not yet been satisfactorily explained.

Dr. E. J. Allen gives a good account of the food of the mackerel, and the method employed by the fish in procuring it, in the Journal of the Marine Biological Association, N.S., Vol. V. The smaller forms of plankton are collected by straining the water through the gill-rakers as it swims along. Young

fish, such as sand eels, sprats and rockling, are hunted and captured. In the early part of the summer such forms as copepoda, larval decapoda, and ctenophora usually constitute the main food supply. Towards the end of the summer one generally finds various kinds of young fish in the stomachs. The purity or mixture of the stomach contents gives a fairly sure indication as to whether the plankton contains a particular kind of organism in abundance, or if there is a variety with none more plentiful than another.

The mackerel caught off Walney on June 30th, the first favourable day for fishing after they were reported to be in the area by one of the pilot boats, proved to have been feeding on a very mixed diet. The food consisted of the following:—Copepoda, *Calanus*, *Temora*, *Centropages*, *Isias*, *Acartia* and *Oithona*; Decapoda, such as megalopa of crabs, second larval stage of *Nephrops* and larval Pagurids; the ctenophore *Pleurobrachia*, the arrow-worm *Sagitta*, and the pelagic ascidian *Oikopleura*. One of the stomachs was crammed with a perfectly pure sample of *Temora*. Another contained *Temora* in abundance along with a number of *Isias*. All the others contained a general mixture of the organisms. The occurrence of a fish with pure stomach contents, in a sample where the majority have a mixed diet, may be explained by the fish having probably passed through a swarm of *Temora* just previous to its capture. It may also have been caught some distance away from the others, as a sailing boat traverses many miles in half a day's fishing. When the first sample of mackerel was examined, *Pleurobrachia* was present in small numbers in the plankton. A rapid increase took place in the first week of July. During the next two weeks the sea along the north-west coast of Lancashire swarmed with this organism, which was quite visible to the naked eye from the deck of a boat. The abundance of ctenophora evidently presented the mackerel with a suitable food supply, as every fish examined during the first two weeks

of July had its stomach packed full with *Pleurobrachia* in various stages of digestion. At the lower end of the stomach the organisms were quite broken down into a soft granular reddish coloured mass. At the upper end and in the oesophagus the *Pleurobrachia* were almost entire. They were easily recognisable. A few second stage larvae of *Nephrops* were invariably mixed with the *Pleurobrachia*. Clupeoid and Polychaet remains, *Calanus* and *Temora*, and the amphipod *Hyperia* were also occasionally noticed. While ctenophora were abundant, and formed the food supply of the mackerel off Walney, quite a different state of affairs was prevailing round about Mull, where Professor Herdman happened to be with his S. Y. "Runa." In a letter from Tobermory Bay, dated July 12th and published in "Nature" on July 17th, he writes "On arriving in the bay last night we found the local boats had been catching abundance of mackerel close to. We bought some for supper (good fish for a halfpenny each), and on dissection found that the stomachs of all of them were crammed full of fresh-looking *Calanus* (the individual copepods for the most part distinct and perfect), along with a few immature *Nyctiphanes* and larval decapods." A sample of the plankton was taken later on in the evening and an ordinary coarse tow-net caught 20 c.c. of the copepoda in five minutes which was estimated to contain 6,000 *Calanus*. Professor Herdman found that the stomach contents of a single mackerel contained about the same amount of *Calanus* as the tow-net caught in five minutes.

The invasion of *Pleurobrachia* began to die away in the area off Walney about the middle of July, and although it continued a conspicuous object in the stomach contents, a more mixed diet was gradually making its appearance. The mixture was rather different from what was observed at the end of June. The copepoda were represented by *Calanus* and *Temora* only. The Cladocera *Evadne* and *Podon* were now

FIG. 1.

FIG. 3.

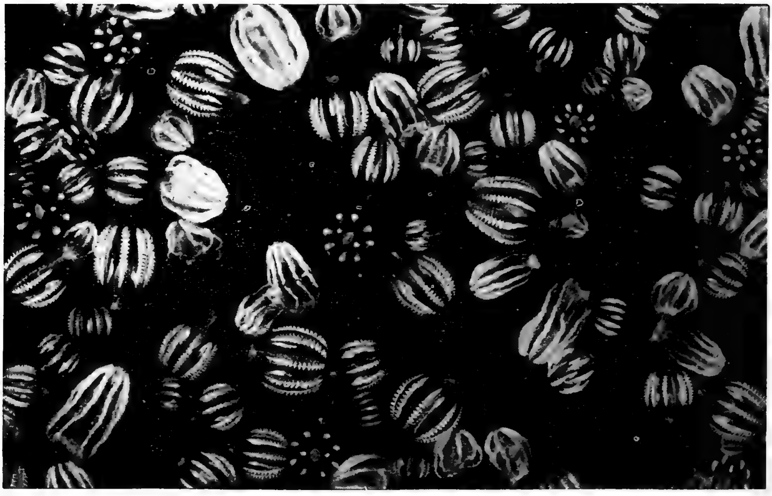


FIG. 2.

FOOD OF MACKEREL.

present. The larval decapods observed in June were again numerous, and the Trachelifer stage of *Jaxea* was not uncommon. The pelagic worms *Sagitta* and *Tomopteris* were frequently noticed amongst the stomach contents. A few medusoids were observed and one young *Sepiola*. Several stomachs contained young rockling which had their stomachs filled with *Temora*. No *Oikopleura* were noticed. The last sample of mackerel was examined on September 8th, and very few of the fish had food in their stomachs. One contained two sand eels 12 cms. in length. Another contained digested fish which were probably sand eels also. It is quite evident that mackerel feed on the plankton around them, and make little or no attempt to select the organisms. The abundance of the fish and duration of their visit to any area will be influenced considerably by the richness of the plankton.

EXPLANATION OF PLATE.

Fig. 1. Nearly pure *Temora* catch from the stomach of a Mackerel. A few specimens of *Isias* were present, and one is shown in the photograph.

Fig. 2. Plankton consisting of *Pleurobrachia* and *Beröe*.

Fig. 3. Larval Decapods from the stomachs of Mackerel.

[From photographs by A. Scott.]

ON THE PELAGIC FISH EGGS COLLECTED IN 1913.

By Andrew Scott, A.L.S.

Samples of the plankton were taken during the various cruises of the S. S. " James Fletcher " in the Irish Sea, Cardigan and Carnarvon Bays throughout the year. Pelagic fish eggs were observed in eighty-three of the collections made between January 23rd and August 14th, the two dates being the first and last occasions when eggs appeared to be present in the plankton. For a period of about eight weeks, extending from February 17th to April 21st, when the classes were held at Piel, the steamer visited the spawning grounds lying between Lancashire and the Isle of Man each week. These expeditions were made to trawl for spawning fish for dissection by the fishermen, and to collect the plankton. Fully one-third of the total number of collections containing eggs were obtained in that time. Some of the samples consisted of little else than eggs belonging to various species of fish. Others contained one or two eggs only. The difficulties experienced in identifying preserved eggs are pointed out in the report " On the Pelagic Fish Eggs collected off the South-West of the Isle of Man," which was published in last year's Annual Report. It is unnecessary to restate them here. It is sufficient to remember that in many cases the identification must be regarded as only approximate.

Illustrations of a fish larva that hatched out from one of three large pelagic eggs with an oil globule, and measuring over 3 millimetres in diameter, are given in the XIII Annual Report, page 32. These eggs were found in a collection of living plankton brought from the Clyde by the first Fisheries steamer " John Fell," where she had been trawling by permission of the Fishery Board for Scotland on April 21st, 1898. The larva

hatched in a glass jar at Piel a few days after the catch was landed. It was suggested in the XIII Annual Report that the eggs might belong to the halibut, as it is the only British fish that spawned an apparently pelagic egg approaching the size given, and which was not enclosed in a ribbon-like mass. Very little was known about halibut eggs at that time, but various investigators have since described them. Professor E. Ehrenbaum in his report "Eier und Larven von Fischen, andere Eier und Cysten" in "Nordisches Plankton," Bd. I, page 179, describes the eggs as 3·1 to 3·8 millimetres in diameter, with a homogeneous yolk, *without* oil globule, and with a tough egg-shell. It is evident, therefore, that the large eggs from the Clyde cannot be halibut as they had a distinct oil globule. Some time after the illustrations were published I examined living eggs and larvae of the angler fish (*Lophius piscatorius*, Linn), and am now fairly certain that the eggs supposed to be halibut really belonged to the angler-fish, and had by some means become separated from the characteristic gelatinous ribbon. The occurrence of such isolated eggs of the angler-fish appears to be very rare, as I have not met with them in the plankton again until 1913. A sample taken off Port Erin on March 10th, 1913, by Professor Herdman in his S. Y. "Runa," contained one of these eggs. It measured 2·74 millimetres in diameter. The oil globule was yellowish in colour and measured 0·59 millimetre in diameter. The egg is rather larger than Ehrenbaum describes on page 47 of his work in Nordisches Plankton. He gives the size of the egg of the angler-fish as 2·13 to 2·36 millimetres in diameter, and the oil-globule 0·53 to 0·57 millimetre in diameter. No doubt there will be a considerable amount of variation both in the size of the egg and of the oil-globule, similar to what is found in the eggs of other fishes.

The following is a summary of the occurrence and distribution of the eggs in the plankton collected by the steamer

during the year. The arrangement is the same as that adopted in the XXI Annual Report published in 1913.

Clupea sprattus, Linn.—Sprat.

The eggs were found in the plankton collected in Carnarvon Bay and along the North Wales Coast from the middle of May to the end of the month. They occurred in Cardigan and Red Wharf Bays in the beginning of June, and off Nelson Buoy in the middle of June. No sprat eggs were found in any of the July collections. One sprat egg was found in a sample of plankton taken in Carnarvon Bay on August 14th. So far as numbers show, the maximum spawning period of the sprat occurred about the end of May. A sample collected six miles N. of Great Orme's Head on May 29th contained seventy-two eggs. Another sample taken in Red Wharf Bay on the same date had twenty-seven. A collection from near the Causeway Buoy, in Cardigan Bay, on June 4th contained thirty-five sprat eggs. The numbers diminished rapidly after these dates, and the eggs ceased to be represented in the plankton taken after August 14th.

Gadus callarias, Linn.—Cod.

The first eggs of the cod were found in plankton collected five miles E. of Point Lynus on February 6th. They were present in thirty-three samples taken in various parts of the Irish Sea from Bahama Bank to off Point Lynus, between the date given and May 9th. The numbers present in the samples gradually increased until the period between March 18th and April 15th when the maximum was apparently reached. After the latter date they diminished, and finally disappeared from the plankton in the second week of May. Plankton samples collected half way between the "Hole" and Bahama Bank on March 18th; eight miles E. ½ S. of Point Lynus on April 3rd; twenty miles W.N.W. from Piel Gas Buoy on April

15th and twenty-five miles W.N.W. from Piel Gas Buoy on the same date contained an average of six hundred cod eggs per sample.

Gadus aeglefinus, Linn.—Haddock.

During the two years previous to 1913 no haddock eggs were observed in any of the plankton samples. Only two records were obtained in 1913, and from the number of eggs present it is probable that spawning fish were very scarce. Two haddock eggs were found in plankton collected five miles N.W. by W. from Peel, Isle of Man, on May 7th. A few adult fish were caught in the trawl net which was being worked at the same time. A sample of plankton from Carnarvon Bay on May 15th contained eleven haddock eggs.

Gadus merlangus, Linn.—Whiting.

The eggs of the whiting made their appearance in the plankton for the first time in 1913, in a collection taken five miles E. of Point Lynus on February 6th. They were present in variable numbers all over the Irish Sea, from Bahama Bank to off Point Lynus, between the date mentioned and May 19th. The eggs extended shorewards to the Selker Light Vessel off the Cumberland coast to Nelson Buoy at the entrance to the Ribble. The maximum spawning period was probably early in April and slightly later than the cod. A tow-netting taken twenty-five miles W.N.W. from Piel Gas Buoy on April 15th contained two thousand four hundred eggs of whiting.

Gadus virens, Linn.—Green Cod, Coal-Fish.

Eggs identified as those of the green cod or coal-fish were observed in five tow-nettings taken between the "Hole" and Bahama Bank, and Bahama Bank and Selker Light Vessel, on February 18th. They were present again on March 3rd, fifteen miles W.N.W. from Piel Gas Buoy. These are the only records which there was any certainty about.

Gadus luscus, Will.—Bib.

The eggs of this fish were fairly plentiful and generally distributed over the whole of the Irish Sea from Point Lynus to Bahama Bank, and shorewards as far as Selker Light Vessel and Nelson Buoy, between February 2nd and May 19th. Considerable numbers of the eggs were found in plankton collected on March 17th, between Selker Light Vessel and Bahama Bank, and on the following day half way between Bahama Bank and the "Hole." One thousand two hundred bib eggs were present in a sample collected twenty-five miles W.N.W. from Piel Gas Buoy on April 15th. A large number of various kinds of fish eggs appeared to be floating about off Nelson Buoy on May 9th, as the sample of plankton which was taken was estimated to contain five thousand bib eggs alone.

Gadus minutus, Linn.—Poor Cod.

Eggs which appeared to belong to the poor cod were observed for the first time in plankton collected eight miles E. ½ S. of Point Lynus, and nine miles S. of South Stack on April 3rd. They were generally distributed over the Irish Sea in May. A collection taken twenty-four miles W.N.W. from Piel Gas Buoy on May 5th was estimated to contain four thousand eight hundred eggs of poor cod. The eggs were present in Carnarvon Bay on May 27th. The last poor cod eggs observed were found in plankton collected five miles W.S.W. from Duddon Buoy on June 6th.

Onos spp., Risso.—The Rocklings.

The eggs of a species of rockling were found in plankton collected five miles E. of Point Lynus, on February 6th. They were generally distributed in the Irish Sea from Bahama Bank to off Point Lynus, and shorewards to Selker Light Vessel and Nelson Buoy, during the months of February, March, April, May, June, and July. They were present in Red Wharf Bay in May and June. They occurred in Cardigan

and Carnarvon Bays in May, June, and July. Rockling eggs were more abundant in the plankton collected in the month of May than in any of the other months mentioned above. The largest number were obtained from a sample collected off Nelson Buoy on May 9th. It was estimated that one thousand five hundred eggs were present. Eight hundred were found in another sample from the same area collected on May 19th.

Ctenolabrus rupestris, Linn.—Jago's Goldsinny.

A very small pelagic egg, which was identified as that of Jago's Goldsinny, occurred four times in the plankton collected in July and August. It was found in Carnarvon Bay on July 2nd; Cardigan Bay on July 6th; South end of Blackpool closed ground on July 25th; and off Great Orme's Head on August 7th. The sample taken off Blackpool contained thirty-four goldsinny eggs, which was the largest number obtained.

Scomber scomber, Linn.—Mackerel.

It is rather surprising that although there was a great abundance of this fish in the Irish Sea in the summer of 1913, only three eggs were obtained and each one from a widely different area. One was found in plankton collected at the entrance to the Mersey on July 8th. Another in Carnarvon Bay on July 22nd, and the third in Tremadoc Bay also on July 22nd. It is probable that very few of the fish spawned in the Irish Sea during their visit.

Psetta laevis, Rondel.—Brill.

Eggs, identified as brill, were found on two occasions in the plankton collected by the steamer in 1913. Two were obtained from a sample taken ten miles N.N.W. from Piel Gas Buoy on June 2nd. Another two were present in a shear-netting taken near Carnarvon Bay Light Vessel on June 4th.

Psetta maxima, Linn.—Turbot.

The eggs of this fish were also taken twice in the plankton collected by the steamer in 1913. Six were found in the collection taken ten miles N.N.W. from Piel Gas Buoy on June 2nd. Three occurred in a sample collected near the Causeway Buoy in Cardigan Bay on June 4th.

Zeugopterus punctatus, Bl.—Muller's Top-knot.

The pelagic eggs of a top-knot which were identified as belonging to the above fish were found in plankton collected in Red Wharf Bay on May 29th, June 5th, and June 11th. They were also present in Tremadoc Bay on July 22nd. That sample contained 12 specimens. The three samples from Red Wharf Bay only contained four top-knot eggs altogether.

Lepidorhombus megastoma, Donov.—Megrim.

The eggs of the megrim or sail fluke appeared to be generally distributed in the Irish Sea from Point Lynus to the vicinity of Bahama Bank, and shorewards as far as Nelson Buoy, in April and May. The maximum spawning period was probably about the last fortnight in April. A collection of plankton, taken nineteen miles N.W. by W. from Morecambe Bay Light Vessel on April 17th, contained four hundred and ninety-six megrim eggs. Another sample, from twenty-four miles W.N.W. from Piel Gas Buoy on May 5th, had three hundred eggs of this fish.

Pleuronectes platessa, Linn.—Plaice.

The pelagic eggs of this important food fish, although generally distributed in the Irish Sea between Lancashire and the Isle of Man from the beginning of February to the middle of April, were very scarce. They occurred in nineteen samples taken during the period mentioned, but the average number of eggs present was only about 3 per sample. The eggs were observed for the first time in four tow-nettings taken on

February 2nd between Bahama Bank and Selker Light Vessel. The last plaice eggs were from a sample of plankton collected half-way between Bahama Bank and the "Hole" on April 17th. The following table shows the distribution and numbers of plaice eggs obtained from the plankton collected by the steamer in 1913.

Position.	Date.	Number of eggs present.
5 miles W. by S. of Selker Light Vessel	18/2/1913	1
Bahama Bank	18/2/1913	2
Selker Light Vessel	18/2/1913	3
Between Bahama Bank and Selker Light Vessel	18/2/1913	8
Duddon Buoy	24/2/1913	2
10 miles W. from Duddon Buoy	24/2/1913	2
1 mile S. from Duddon Buoy	24/2/1913	1
20 miles N.W. ½ N. from Piel Gas Buoy	25/2/1913	1
15 miles S.W. from Morecambe Bay Light Vessel	26/2/1913	1
10 miles N. from Great Orme's Head	26/2/1913	1
10 miles S.W. from Morecambe Bay Light Vessel	26/2/1913	2
Selker Light Vessel	17/3/1913	6
Between Selker Light Vessel and Bahama Bank	17/3/1913	9
Bahama Bank	18/3/1913	2
25 miles W.N.W. from Piel Gas Buoy	18/3/1913	2
½ way between "Hole" and Bahama Bank	18/3/1913	10
15 miles W.N.W. from Piel Gas Buoy	15/4/1913	2
Morecambe Bay Light Vessel	15/4/1913	1
½ way between Bahama Light Vessel and "Hole"	17/4/1913	3

Pleuronectes limanda, Linn.—Dab.

The first dab eggs were observed as early as February 24th in plankton collected one mile S. from Duddon Buoy. They appeared to be generally distributed all over the Irish Sea from Bahama Bank to Red Wharf Bay and Nelson Buoy during March, April and May. Dab eggs were present in plankton collected in Carnarvon Bay on May 13th and 28th. The maximum spawning period of this fish occurred probably early in May. A tow-netting taken twenty-four miles W.N.W. from Piel Gas Buoy, on May 5th, contained two thousand four hundred eggs of the dab. Another sample, taken at Nelson Buoy on May 9th, was estimated to contain three thousand five hundred eggs of dab along with the pelagic eggs of other species of fish.

Pleuronectes flesus, Linn.—Flounder.

Flounder eggs were recognised for the first time in the plankton collected in the Irish Sea in 1913, five miles W. by S. from Selker Light Vessel on February 18th. They were generally distributed in the northern area of the Irish Sea from the date mentioned to the middle of April. The numbers present in the samples of plankton were never very large, and only exceeded one hundred on three occasions. A collection taken twenty-two miles W.N.W. from Piel Gas Buoy on March 3rd, contained one hundred and twenty. Another sample, from half-way between the "Hole" and Bahama Bank on March 18th, contained four hundred and eighty. The third time the hundred was exceeded was in a sample taken nineteen miles N.W. by W. from Morecambe Bay Light Vessel on April 17th, when two hundred and eighty-eight flounder eggs were found.

Pleuronectes microcephalus, Donov.—Lemon Sole.

Pelagic eggs which were identified as those of lemon sole were found in plankton collected nine miles S. of South Stack on April 4th. They occurred again five miles N.W. by N. from Peel, Isle of Man, on May 7th. Collections taken in Red Wharf Bay on May 15th, 20th, and 29th, and again on June 5th, contained an average of thirty-one lemon sole eggs each. Plankton collected six miles N. from Great Orme's Head on May 29th contained forty-two eggs of this fish. Lemon sole eggs were not observed after June 5th.

Pleuronectes cynoglossus, Linn.—Witch.

The pelagic eggs of the witch were only found on one occasion in 1913. Fifteen were present in a sample of plankton collected five miles N.W. by N. from Peel, Isle of Man, on May 7th. The adult fish are found in fair quantities West of the Isle of Man and off Calf Island, but they are not often met with between the Isle of Man and Lancashire.

Solea vulgaris, Quen.—Sole.

The characteristic pelagic eggs of the sole were only observed in five samples of plankton, and with one exception the numbers present were quite small. They were first found twenty-four miles W.N.W. from Piel Gas Buoy on May 5th. This collection was estimated to contain three thousand six hundred sole eggs. Plankton collected nine days later at almost the same place had only one sole egg. Four sole eggs were observed in a sample collected thirteen miles S.W. from Morecambe Bay Light Vessel on May 14th. They were present in Carnarvon Bay on May 27th and June 4th.

Solea lutea, Risso—Solenette.

Small pelagic eggs with many oil-globules, which were identified as those of the solenette, were found in plankton collected in Carnarvon Bay on May 15th and 27th, and on June 3rd. They occurred near the Causeway Buoy in Cardigan Bay on June 4th and in Tremadoc Bay on July 6th. They were also present off Nelson Buoy on May 24th and on June 12th.

Trigla gurnardus, Linn.—Grey Gurnard.
Trigla cuculus, Linn.—Red Gurnard.
Trigla lucerna, Linn.—Yellow Gurnard.

The pelagic eggs of the three common species of Gurnard were almost certainly present in the plankton collected by the steamer in 1913, but as the sizes of the eggs of the three species overlap, it is quite impossible to separate them. Gurnard eggs were first observed in plankton collected nine miles S. of South Stack on April 3rd. They were afterwards present at the following stations:—five miles N.W. by N. from Peel, Isle of Man, on May 7th; thirteen miles S.W. from Morecambe Bay Light Vessel on May 14th; in Carnarvon Bay on May 15th and 27th; in Cardigan Bay on May 21st; in Red Wharf Bay and six miles N. of Great Orme's Head on May 29th.

Trachinus vipera, Cuv. and Val.—Lesser Weever.

The eggs of the lesser weever or sting-fish appeared to be generally distributed in the coastal waters of the Irish Sea, Cardigan and Carnarvon Bays in May, June, July, and August. They were rarely met with in the plankton collected in the central area. The number of eggs present in the plankton usually ranged from one to eighteen. A collection taken in Carnarvon Bay on June 3rd, however, contained sixty-four lesser weever eggs.

Callionymus lyra, Linn.—Dragonet.

The characteristic eggs of the dragonet, which can be readily recognised by the hexagonal markings on the outside of the shell, were observed as early as January 23rd in a sample of plankton collected in Ramsey Bay. The eggs were generally distributed in the off-shore and coastal waters of the Irish Sea until June 5th. One sample collected twenty-four miles W.N.W. from Piel Gas Buoy on May 5th was estimated to contain nine thousand six hundred dragonet eggs. Another from near Nelson Buoy on May 9th contained one thousand eggs. Plankton collected in Carnarvon Bay on May 15th contained fifty-one dragonet eggs. Another collection taken on May 27th contained one hundred eggs. Dragonet eggs apparently disappeared from the Irish Sea after June 5th, and from Carnarvon Bay after July 22nd. The eggs in one of the large catches were measured to find out how much variation in size occurred amongst them. It was found that the smallest egg measured 0·72 mm. in diameter, and the largest egg 0·86 mm. in diameter—a difference of 0·14 mm. McIntosh and Masterman give the size as 0·686 mm. in diameter. Professor Ehrenbaum gives the size as 0·69 mm. to 0·94 mm. in "Nordisches Plankton." There is evidently a considerable variation in the size of the eggs of the dragonet in the North Sea and in the Irish Sea.

INTERNAL PARASITES AND DISEASED CONDITIONS OF FISHES.

By Jas. Johnstone, D.Sc.

Contents.

Didymozoon scombri, Taschenberg.—Plates I and II.

A number of specimens of this interesting Trematode were found by Mr. A. Scott, when examining small mackerel caught in the Irish Sea just outside Walney Island, in Lancashire. Odhner* has given a very full and accurate account of the anatomy of the animal, all the details of which I have been able to verify. Nevertheless these particular specimens may be worth describing shortly.

The worms were contained in cysts (1) on the roof of the mouth beneath the pharyngo-branchials: this was the most common situation; (2) on the basi-branchials; (3) on the external surfaces of other parts of the gill bars; (4) on the internal surface of the operculum. Usually the cysts were single ones, but rarely there was a group of them. They usually measured about 4 to 5 mm. by 2 to 3 mm., but one or two were much larger. They were light-yellow in colour because of the eggs within, which showed through the delicate

* Odhner, T. "Zur Anatomie der Didymozoen: ein getrenntgeschlechtlicher Trematode mit rudimentären Hermaphroditismus." In *Zoologiska Studier tillagnade*, Professor T. Tullberg, pp. 309-342, 1 Plate, Uppsala, 1907.

walls of the duct and that of the cyst. They were easily ruptured when they were removed. One cyst dissected by Mr. Scott contained 13 large and 3 small worms.

Fig. 1, Pl. II, represents a section through one of the smaller cysts which had been dissected out. This cyst, and another one examined in section, contained two worms, and the heads of these worms are shown in the figure. The bodies of the worms are coiled round each in a way suggested by the figure, so that it is difficult to trace one individual through the series of sections, but one can be certain that only two worms are contained in the cyst. The integuments of the two individuals, and even that of different coils of the same individual, are applied to each other very closely, so that examination of the section under a high magnification fails to resolve these apposed integuments. The two worms cannot be separated from each other by dissection, and it seems certain that, in some of these cysts there is an actual organic fusion of the individual worms. Nevertheless it is impossible to trace any connection of the two systems of genital organs.

The cyst has a distinct, thin wall of its own, which is very easily ruptured on dissecting it out from the tissues of the host. Here and there in the section there are spaces between the coils, and these spaces are usually filled with eggs. It may be that these eggs have issued from the female genital opening, either naturally, or on the contraction of the cyst following preservation and embedding, but it is more probable that the uterus becomes ruptured in places and that the eggs thus escape.

The shaded parts in the figure represent those parts of the tissues of the worm where the typical "parenchymatous" tissue occurs. The small dark bodies are sections of either the vitelline gland or the ovary: it is sometimes difficult to be sure which when the position of the section is unknown.

The sections of the uterus can be recognised by the presence of the eggs. The apparently empty spaces in the section, or those which contain fine granular matter are sections of the branches of the alimentary canal and of the large excretory canals.

Only one of the cysts examined—one which was situated on the external surface of an outer gill-bar, contained separate worms. About half a dozen of these were dissected out by Mr. Scott, and the worms were fixed and stained. They varied in length from about $1\frac{1}{2}$ to 2 cms., and in diameter from $\frac{1}{2}$ to rather more than 1 mm. The worm had a distinct neck, and the hinder part of the body was thicker than the neck, but there was no large expansion of the posterior body, like that present in some other species belonging to the group. The worms coil up spirally and cannot easily be straightened out during fixation. One was straightened out during the process of dehydration, and even cut into serial sections, but the process of straightening led to the collapse of the branches of the alimentary canal, and the excretory canals, so that it was difficult to trace the genital ducts in these sections. Another worm was cut longitudinally as the coiling after death took place in one plane. Pl. I, which represents the arrangement of the genital organs, is based almost entirely on this preparation. The most conspicuous organ is, of course, the female genital duct. This starts from the shell-gland as a short thin oviduct and then runs forward as a narrow duct; it is the first segment of the uterus, and contains small, round, thick-shelled eggs. Near the anterior end of the body it turns back and runs posteriorly as the second part of the uterus, and then reaching the posterior end of the body it runs forward again as the third segment of the uterus. It dilates greatly in some of the worms near the anterior end. Then there is a short, thick-walled, very narrow, efferent genital duct which opens at the tip of the genital papilla.

There is a thick-walled, narrow duct which runs along the convex margin of the worm (that is, the latter coils so that this margin is always the convex one). This duct is apparently continuous throughout. It is very much coiled and twisted—much more so than is represented in the figure, but it lies, on the whole, on the convex side of the worm. Looking at it closely we see that its anterior part is structurally different from the posterior part, and the transition from one part to the other occurs in the region of the shell-gland. The actual disposition of the parts in this region is represented in fig. 2, Pl. II. The calibre of the duct in question suddenly diminishes and it is joined by a short fine duct coming from a receptaculum seminis, and almost at the same place another fine duct leaves it. The latter is the oviduct, and this is surrounded, at its origin, by a shell-gland entirely similar to the homologous organ in other Trematodes. The oviduct, convoluted at this region, then enlarges in calibre and passes into the first segment of the uterus. The anterior part of the fine duct we have mentioned is the ovary: the posterior part is the vitelline gland.

The male organs are greatly reduced. There is a very fine efferent duct opening close to the female genital orifice on the tip of the genital papilla. This enlarges to form a feebly-convoluted duct, similar to the structure called the vesicula seminalis in most Trematodes, but which Odhner calls the unpaired vas deferens. The distal part of this is the greatest in calibre. From it two very fine short ducts proceed, and these rapidly enlarge to form thick, richly-convoluted ducts—the paired vasa deferentia of Odhner. Then they are continued into short, narrow, feebly-coiled ducts, called the testes by Odhner. There are no traces of prostate gland or intromittent organ.

In Pl. I, the various genital ducts have been "straightened-out." Their convolutions are really far more complex than is represented in the figure.

Myxosporidian Infection in the *Anarrichas lupus.*

A large catfish (*Anarrichas lupus*) sent to me by Mr. F. Stokes was the subject of an extraordinarily rich infection by a species of sporozoan. Dr. H. M. Woodcock, who saw some of the tissue from this fish, identified the organism as a species of Pleistophora, possibly new. Dr. H. C. Williamson* has also described a similar condition in *Anarrichas* and regards the parasite found as identical with *Pleistophora hippoglossoides,* Bosanquet; while Drew† also describes a new Pleistophora from the muscles of the cod. It is not at all certain, however, that the organism referred to here is identical with either of those described by Williamson and Drew, and pending Dr. Woodcock's investigation of its nature I only describe the infection briefly. The *whole* fish, one about 27 inches in length, was infected. All the flesh was knobby, as if large marbles had been inserted some little distance beneath the integument. On cutting into it, it was seen that these protuberances were the result of the swelling of large blocks of muscle fibres, and the swellings were also seen to be the result of the deposition within the fibres of ripe cysts crowded with ripe spores. No part of the flesh of this fish appeared to be quite free from infection, but underneath the visible protuberances the alteration of the normal muscle tissue was profound. The ripely infected tissue was grey-green in colour and very soft, so that on cutting into it it seemed to be fluid, a condition due, probably, to the autolysis of the connective tissue remains of the muscle fibres and bundles, and the liberation of the ripened spores.

Ovarian Degeneration in a Cod.—Plate III.

In March of this year Mr. T. R. Bailey, Port Sanitary Inspector at Fleetwood, sent me an ovary taken from a cod,

* *Ann. Report Fishery Board for Scotland Sci. Invest.*, 1911, II., (March, 1913), p. 16, Pl. III, figs. 59-62.

† *Parasitology,* Vol. II., 1909, p. 193, Pl. 1.

which appears to be the subject of some obscure degenerative process. In its external appearance the ovary presented no very remarkable features: it was about the normal size and weight, and its shape was also very much what one usually finds. On cutting through it Mr. Bailey found, however, that the central part of the roe was occupied by a homogeneous irregularly shaped mass, having the consistency of cheese. He preserved the organ in 5% formalin and sent it to me, but it had been in the preservative for a month or two before I had an opportunity of making a minute examination of it.

Fig. I, Pl. III, is reproduced from a drawing of a longitudinal section of the ovary. The figure is reduced, and the section was made some distance to one side of the middle line of the organ, so that it does not represent the full size of a median section. The peripheral parts of the ovary are perfectly normal, the serous coats are present and also the germinal epithelium, and some of the coarser folds, or septa, of the latter are represented. The ova are present in this peripheral part just as they are in the normal ovary. The fish was taken in March, at the time of year (for the north-west coast of England) when many cod are just maturing before spawning begins. At this time the ovaries of the fish are firm and opaque in colour, the serous coats are relatively thick, the eggs are small and opaque, and they are still adherent to the septa of germinal epithelium which traverse the internal parts of the ovary. With maturation the whole organ swells because of the imbibition of water by the ova, and the serous coats and germinal epithelium become thin and almost transparent. The ova swell up and also become transparent, and they become loose from each other and the germinal epithelium, so that when the roe is cut into, the eggs "run," that is, because of their freedom from each other, and their almost perfect transparency, the contents of the ovary appear to be liquid. In a cod, or other gadoid fish, most of the ova mature at about the

same time, so that the act of spawning extends over relatively few days. In this specimen the eggs in the peripheral parts of the affected ovary are quite normal for the stage of development of the organ, and they look as if they would have proceeded to complete maturation, but whether these ova would have been spawned in the normal manner is, of course, uncertain.

The degenerative mass in the central part of the ovary was evidently much harder than when it was examined in the fresh condition by Mr. Bailey. After about two months preservation in 5% formalin it had the consistency of hard cartilage. It had rather the appearance of a fibrous cartilage, except that it was yellow-brown in colour, and very finely granular. Round the marginal parts there was a very evident lamination, but in the central parts this was not at all distinct. The mass was very irregular in shape so that the successive sections through the roe presented very different appearances. It seemed to be growing, or rather the degenerative changes appeared to be proceeding, at different parts of the originally unmodified mass of ova, so that here and there were small masses of eggs surrounded by the new substance, and in some of these small areas the eggs were breaking down, apparently becoming transformed into the cartilaginous substance of the neoplasm.

Fig. 2, Pl. III, represents a hand section through the margin of the altered substance. The unmodified ovarian tissues are not shown, but the lower part of the figure is that towards the external part of the ovary, and a single ovum, not much modified, is shown. The section has been treated with an aqueous solution of silver nitrate and then exposed to light, dehydrated and mounted in balsam. The blackened portion is the margin of the concretion : it is shown less highly magnified in Fig. 1. In Fig. 2 it is seen to be a layer of some width, in which there is a sheet of some substance

taking the silver impregnation more deeply than the rest. The upper part of the figure represents the structure of the concretion within the concentric, deeply impregnated capsular structure.

The material of the concretion becomes very hard on dehydration and embedding in paraffin, so that thin, microtome sections cut in this way break up easily, and it is difficult to make out their structure. It is apparent, however, that the greater part of this laminar marginal part of the concretion is a product of cellular proliferation. It is crowded with very small, altered nuclei, which are embedded in a tissue which shows no distinct cell boundaries. This is the structure of the dark part in fig. 2, and directly above it, that is towards the central part of the concretion, is an obscure layer of what appear to have been vacuolated cells, elongated in a direction which is radial to the concretion. External to the dark part, the appearance of the tissues suggests that of a hypertrophied fibrous connective tissue.

The substance of the concretion internal to this dark capsular margin consists of a semi-translucent cartilaginous looking mass, apparently homogeneous to the naked eye. Fig. 3 represents a small part of this—a thin hand-cut section stained with Mayer's haemalum and eosin, and it is now seen that the substance is not homogeneous. It consists of a ground-substance or matrix staining pink, with haemalum-eosin, and in this are strips, or sections of sheets, of some other substance which stains a faint blue with the haemalum. These strips are not homogeneous, for there is a more deeply staining band in the central part of each of them. In the matrix there are numerous granules, and lighter staining parts as well as sheaves of what appear to be crystals, prismatic in form, and with the prisms arranged usually in radial groups.

What all this structure at once suggests is, first of all, an abundant proliferation of the connective tissue in the

marginal part of the ovary, forming a concentric internal capsule, which has then shut off the mass of ova internal to it from the circulation of nutritive fluid in the ovarian sac. In the closed ovarian sac of the teleostean fish the blood vessels are mainly contained in the serous and fibrous layers external to the germinal epithelium. This germinal epithelium projects inwardly, as radial septa, towards the centre of the ovary, and lymph diffuses out from the blood vessels running in these septa, and forms the fluid of the ovarian sac. If a non-permeable capsule were to form all the mass of ova within, it would be shut off from this lymph diffusion, and might possibly cease to mature and break down, both structurally and chemically. The ground substance shown in fig. 3 might therefore represent the altered yolk and other substances of the ova, and the blue bands might be sections of the more resistant capsules of the eggs.

On this view some progressive change has therefore occurred in the ovary, it may be a sarcomatous condition resulting from the over-growth of the connective tissue of the ovarian stroma in a marginal, concentric zone of the organ; and this progressive change has been accompanied with a retrogressive change, and chemical alteration of the substance of the ova.

The whole thing indeed suggests a dermoid cyst. With this idea I searched through it for traces of cuticular or epidermal structures, such as scales, but nothing of this kind could be recognised.

The Chemical Nature of the Deposit.

This has not been fully determined. A part from the inside of the deposit, as nearly homogeneous as possible, was cut into slices and dried at 100° C. The dried material was hard and horny, and did not shrink much (dried at 110° C. the material gave 30·9 % of moisture). On heating the dried

material first charred and then melted with decomposition and burned while melting, at first with a non-luminous flame and then with a smoky flame. The smell was that of horny charring matter, and purin substances could be detected. On igniting strongly the ash was creamy in colour, and not abundant. The ash was dissolved in weak hydrochloric acid and precipitated with ammonia and ammonium chloride, filtered and reprecipitated with ammonium oxalate. The precipitate was weighed as calcium carbonate. From 2·966 grms. of the substance dried at 100° 0·030 grms. of $CaCO_3$ was obtained—less than 1 %.

The deposit is not, then, a calcareous one. Dr. Titherley, of the Organic Chemical Department at the University of Liverpool, made a determination of the nitrogen by Kjeldahl's method. There was 13·03 % of nitrogen in the dried material or about 9 % in the moist. A rough ether extract was made: there was some fat present, but the proportion was not estimated. Since the material was not extracted before analysis, nor purified, the above percentage of nitrogen agrees very well with that of a protein. The preservation (two months in 5 % formalin) had doubtless altered the constitution of the substance, and some small amount of lime may have been dissolved out, but that much lime was so lost is very unlikely. Because of this alteration in the nature of the material it could not be brought into solution, but the zanthoproteic test and the Adamkiewiez test were applied with positive results. The substance, therefore, probably belongs to the group of sclero-proteins, or to that of the conjugated proteins. It is apparently allied to the chondrein proteid substances. The deposit is clearly not a calcareous one, nor can we say that it is a teratoma. Yet the progressive alterations indicated at the margin of the deposit seems to indicate either a teratomatous or a sarcomatous nature; on the other hand the whole appearance of the substance, its microchemical

reactions, and its chemical composition suggest that it is allied, or belongs to the amyloid deposits of human pathology. The iodine test for amyloid substance was applied successfully, and so far as this goes it indicates that this is part of the nature of the deposit.

Epitheliomata in the Turbot.—Plate IV, fig. 1.

A large turbot, which was seized by Mr. T. R. Bailey, Inspector at Fleetwood, was covered with black, raised spots, both on the ocular and blind sides. The fish was very thin and in poor condition, and its eyes were affected by a thickening and opacity of the cornea. The spots on the skin varied in size from about $\frac{1}{2}$ up to 2 cms. Most of them were, apparently, only black pigment spots, many being hardly raised above the general surface of the skin. Some, however, were raised up about 1 to 2 mm., and were only very slightly pigmented. One of these more prominent lesions was cut out, fixed in Zenker's fluid, and sections were made. One of these sections, stained in methyl-blue-eosin, is represented in fig. 1, Pl. IV.

The section includes the integument and part of the underlying systemic muscles: two bundles of the latter are shown. The integument in this fish—a large and full-grown one—consists mainly of a very thick and strong layer of coarse connective tissue fibres. These are arranged in two series, one consisting of bundles of fibres running perpendicularly to the surface of the skin: these are thick and coarse bundles; and another series consisting of bundles which run parallel to the surface of the skin. These two series of bundles cross each other nearly at right angles; between them is a loose fibrous tissue with small cells. Between this coarse fibrous layer and the underlying systemic muscles is a loose areolar tissue, and between it and the epidermis is also a rather coarser areolar tissue containing an interrupted layer of black pigment. The epidermis, that is, an evident squamous epithelium lying

over prickle-cells, can hardly be recognised in the region of normal skin.

The figure shows a flat, wart-like protuberance of the skin, and beneath this protuberance there is a partial disintegration of the coarse fibrous layer. This disintegration is produced by the down-growth of tissue from the dermis or epidermis, and this tissue penetrating between the connective tissue bundles has led to partial absorption of the latter. The intrusive down-growing tissue consists mainly of fine fibres running in various directions, but between these bundles of fibres are cells arranged sometimes in short cords, and there is also an abundant infiltration of lymphocytes.

The lesions suggest sarcomatous conditions, but they are not quite like any of those which I have already seen, and melanism is usually absent in the most typical tumours. The condition rather resembles that of an epithelioma, except that there are no traces of squamous epithelium or prickle-cells. The lesions are, however, atypical ones.

Halibut with Benign Tumours in the Body Muscles.—Plate IV, figs. 5 and 6.

On October 30, 1913, Mr. F. Stokes, Port Sanitary Inspector at Grimsby, sent me a large piece of halibut cut from a fish which had come under suspicion. For certain reasons it became necessary to investigate closely the question of the malignancy or otherwise of growths, or tumours, in the flesh of this fish. The halibut was an unripe female, weighing over 2 cwts., and it was apparently well-nourished and in good condition. On the coloured side, behind the body cavity, there were two large lesions; one of these had been removed, the flesh being cut away round and beneath it, the other was intact. The skin had disappeared over a round area about 10 cms. in diameter. The wound so formed was not sunken, and its surface was level with the surrounding tissue,

but the skin round its margin was slightly raised and thickened. Near this large sore were some smaller ones about 1 to 2 cms. in diameter. Unlike the larger lesion, these were rather deep. In all cases the exposed tissue was creamy in colour and obviously not muscular. There was no pus or blood, and the wounds were quite clean ones.

On feeling the rest of the fish, firm and hard nodular masses could be detected beneath the skin, although they were not visible in any case. On cutting down, these were seen to be rounded or egg-shaped masses, embedded in the muscular tissues. They were opaque and white in colour, usually hard, but in some of them the internal parts had suffered necrosis, and had liquefied. These growths were about 2 to 6 cms. in diameter.

Fig. 3, Pl. II, represents a vertical hand-section through the large lesion. The normal integument is shown at the upper edge of the section, both on the right and left hand sides: on the left, part of a scale is shown in the section. Below there are normal bundles of muscle fibres running in the plane of the paper. The stippled part of the figure represents the locus of the abnormal growth. It occupies a situation below the abraded surface of the body forming the lesion. There are also some other growths in connection with the main one or independent of it.

Fig. 5, Pl. IV, represents a section through a small part of one of these growths as seen under a high-power oil-immersion lens. The tissue is of the "fibro-sarcomatous" type, that is its chief constituent is perhaps a coarse and dense fibrous reticulum as shown in the section. In some places this fibrous tissue is the predominant one, and the growth has all the characters of an ordinary fibroma, but in other places, as in the part figured, the tissue consists mainly of small round cells with large nuclei, and here the growth assumes the character of a sarcoma consisting of small round cells. The cells are

tightly packed together in the interstices of the fibrous reticulum, and here and there this is reduced to a mimimum.

Even the naked-eye appearance of the hand-sections suggests that the growths are encapsulated, for the boundaries are always very definite, although none of the tumours can be "shelled-out." Fig. 6, Pl. IV, represents a section through the margin of one of the larger growths, as seen under a low-power lens. The closely stippled part on the left is the locus of the growth, which has the same characters as are represented in fig. 5, Pl. IV; on the right are muscle fibres cut slightly obliquely. The texture of these muscle bundles is rather loose; they are loaded, in some places, with fat cells; and there is a rather abundant inter-fibrillar connective tissue reticulum, in which, of course, the fat occurs. Between these muscle fibres and the neoplasm is the capsule, composed of bundles of rather coarse connective tissue fibres, with very many small nuclei.

This capsule appears to exist round all the nodular masses. The latter are of various sizes, and appear therefore to be growing, but they are so sharply delimited from the surrounding tissues that one cannot speak of them as malignant in character, in spite of their resemblance to some sarcomatous tissues. The loss of the skin over the surface of the large growth, and the liquefaction in the centres of some of the other tumours, are due to necrosis which is doubtless the result of the very imperfect vascular supply of these formations.

Fibrosis of the Liver in a Conger.—Plate IV, figs. 2—4.

This appears to be the nature of some abnormal conditions of the liver of the conger (as well as that of some other fishes) noticed by Mr. Richard Elmhirst, of the Millport Biological Station. In these fishes the liver contained small, round, hard nodules, easily felt on handling the organ. The nodules were about 2 to 5 mm. in diameter. Some were cut out,

fixed in Bouin's fluid, and given to me by Mr. Elmhirst, and the figs. 2, 3, and 4 of Pl. IV represent the minute anatomy of these structures.

Fig. 4 represents the appearance of a section through one of these nodules as seen under a low-power lens. It is a nearly globular mass of connective tissue, consisting of wavy bundles, running in all directions. There are numerous, irregularly shaped cavities in the section, and towards the centre of the nodule these are quite empty, but towards the margins many of them contain capillaries or other small blood-vessels. The cavities in the central parts of the nodule were probably also those of blood vessels, and the whole structure appears to be a proliferation of Glisson's capsule.

Fig. 2 represents a section of a nodule at the margin of the latter. The fibrous structure is sharply delimited from the surrounding liver parenchyma although there is no concentric capsule, or other limiting layer. Round the periphery of the nodule there is a very rich capillary network, richer than that represented in the figure. Some of these capillary vessels can be traced into the fibrous tissue of the nodule, but most of them appear to be restricted to the immediate neighbourhood of the latter, while still remaining outside it. The fibrosis of the liver is therefore accompanied by an active inflammatory condition.

Fig. 3 shows the minute anatomy of the liver parenchyma in the immediate vicinity of the fibrous nodules. The ordinary liver cells have disappeared, and in their place is the rich capillary blood vascular network, in the interstices of which are numbers of large round cells loosely and irregularly arranged. These cells have large nuclei with prominent nucleoli. The cell body appears to be richly vacuolated, or to have deposits of some unstainable material. Between them is a débris of apparently broken-down cell material. Nothing in this suggests ordinary hepatic tissue, and it appears to be

the result of a strongly inflammatory condition in the localities of areas of active cell proliferation.

Fibroma in the Orbit of a Cod.—Plate V.

The head of a large cod, sent to me in July last by Mr. T. R. Bailey, had the interesting tumour represented in the photograph on Pl. V. This tumour was on the left side of the head, and projected out from the anterior border of the orbit: it was about 7 cms. in height, and about 6 cms. in diameter. It had a shallow constriction separating it into upper and lower parts. It was hard, and dirty-white in colour. The integument over it was apparently normal except that it had been rubbed, or abraded mechanically.

The tumour does not involve any part of the eye, but appears to have grown from the sub-integumentary structures at the anterior margin of the orbit. The excessive growth has pushed the eye back, and down into the posterior part of the orbit, so that it is only just seen in the photograph, immediately behind the tumour, where the sharply marked boundary is, of course, the posterior wall of the orbit. On dissecting into the base of the tumour, the eye and eye-muscles are seen to be quite normal in their size and relations; they are simply overgrown by the tumour.

The growth is, of course, an ordinary fibroma without any indications of malignancy.

EXPLANATION OF THE PLATES.

Plate I. *Didymozoon scombri,* Taschenberg.

A single worm dissected out from a cyst, stained in borax-carmine and cleared. Magnified about 17 dia.

Plate II. Figs. 1 and 2, *Didymozoon scombri.* Fig. 3, Benign tumour from a Halibut.

Fig. 1. A section through a cyst containing two worms. Magnified about 34 dia.

Fig. 2. Semi-diagrammatic representation of the junction of the genital ducts. The figure has been drawn partly from a cleared preparation, and partly from serial sections. Magnified about 140 dia.

Fig. 3. Benign tumour from a Turbot. Section through a lesion on the skin. The uninjured skin, showing some scales *in situ,* is shown on the upper right and left corners of the figure. The stippled area is the *locus* of the tumour. Part of a small capsulated tumour is seen at the lower left corner. Some large bundles of muscle fibres are shown. About two-thirds natural size.

Plate III. Ovarian degeneration in a Cod.

Fig. 1. Longitudinal hand-section through the ovary. Round the margin is the unaltered tissue of the organ; centrally is the degeneration tissue. About five-sevenths natural size.

Fig. 2. Section through the margin of the degeneration tissue. The stain is silver nitrate reduced by exposure to light. Magnified about 40 dia.

Fig. 3. Section through the central part of the degeneration mass. The stain is haematoxylin and eosin. Magnified about 200 dia.

Plate IV.

Fig. 1. Epithelioma from a Turbot. Vertical section through one of the wart-like protuberances on the skin of the fish. The part diagrammatically shaded with fine lines and dots is the new growth. Below this is the broken subdermal coarse connective tissue layer. Below this again is the body musculature. Magnified about 25 dia.

Fig. 2. Fibrosis of the liver in a Conger. The margin of a fibrous nodule seen under an oil-immersion lens.

Fig. 3. The same. Some cells from the altered hepatic tissue round the fibrous nodule.

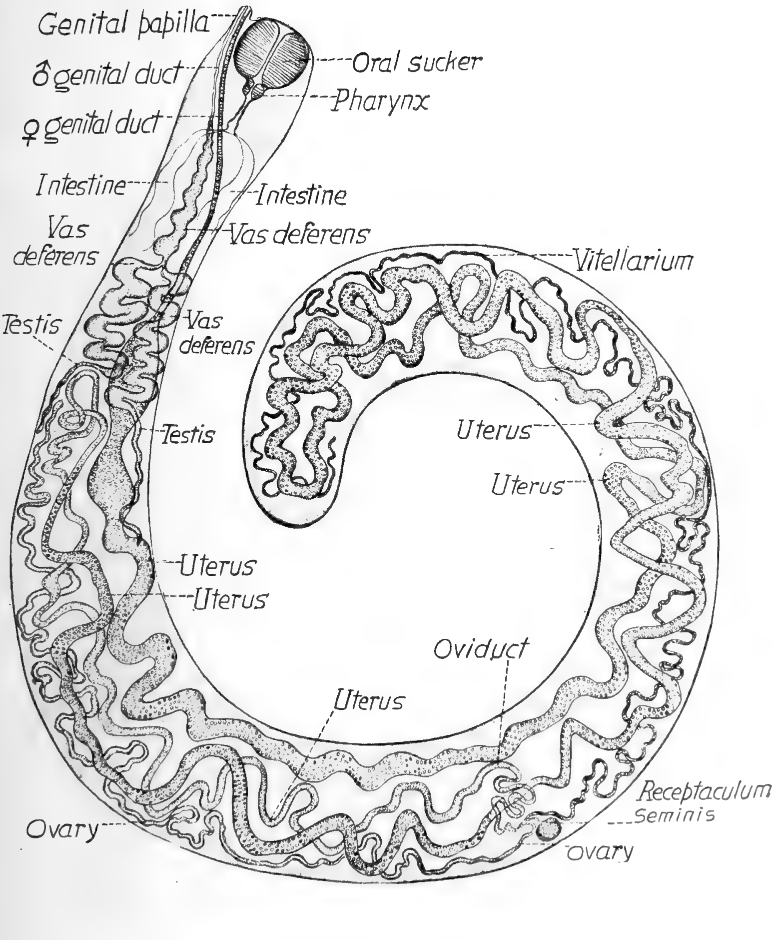
Fig. 4. The same. A fibrous nodule cut meridianally. Centrally is the new growth; marginally the altered hepatic tissue. Oil-immersion lens.

Fig. 5. Benign tumour from the muscles of a Halibut. Details of the structure of the fibroma as seen under an oil-immersion lens. Fine reticulum of connective tissue, with small rounded cells in the interspaces.

Fig. 6. The same. Section through the margin of a tumour. The dark stippled part to the left represents the new growth. On the right are the surrounding muscle fibres in oblique section. This tissue is unaltered. Between these two layers is the connective tissue capsule of the tumour. Magnified about 40 dia.

Plate V.

Fibroma growing on the anterior margin of the orbit of a Cod. About half natural size.



DIDYMOZOON SCOMBRI TASCHENBERG.

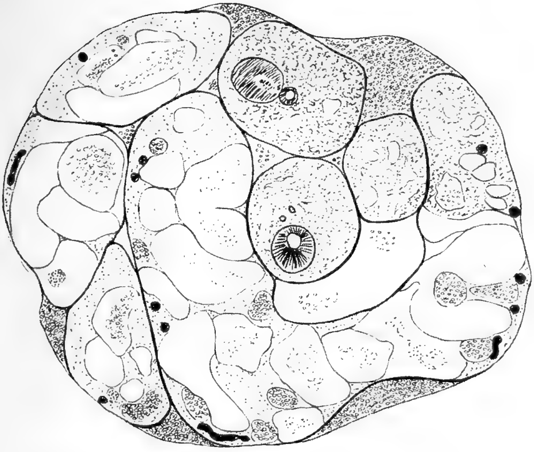


FIG. 1.

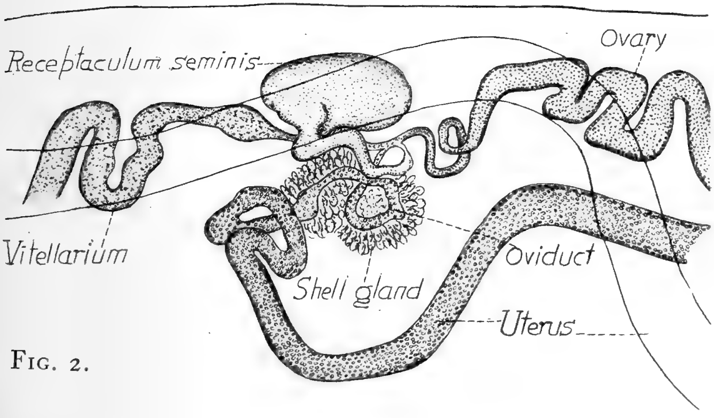


FIG. 2.

FIG. 3.

FIG. 1. *Didymozoon scombri.* Section of a cyst containing two worms.
FIG. 2. *Didymozoon scombri.* Junction of the genital ducts.
FIG. 3. Benign tumour in a Halibut.

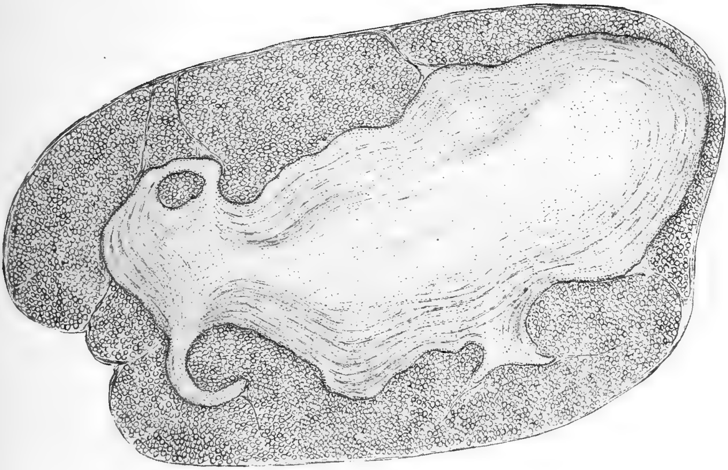


FIG. 1.

FIG. 2.

FIG. 3.

OVARIAN DEGENERATION IN A COD.

FIG. 1. Longitudinal section of the ovary with the degeneration mass *in situ*.
FIG. 2. Section through the margin of the degeneration mass.
FIG. 3. Section through the central part of the mass.

Plate IV.

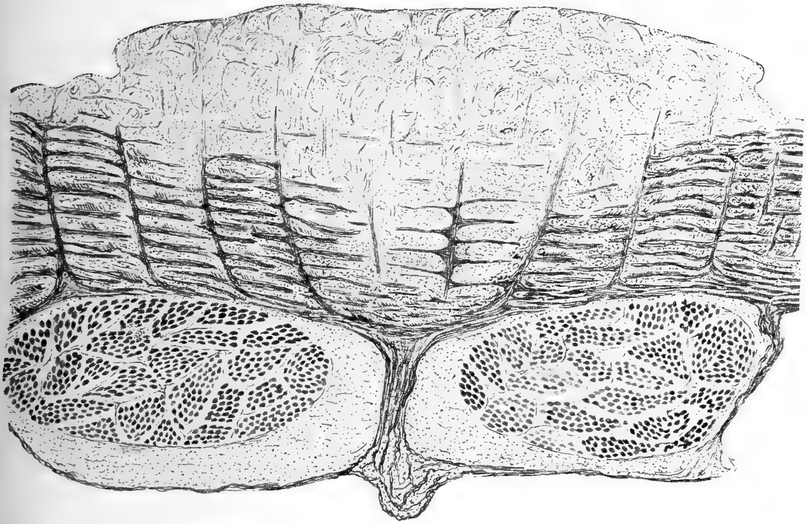


Fig. 1.

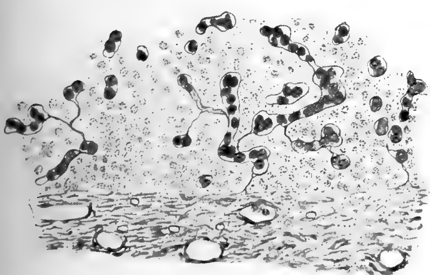


Fig. 2.

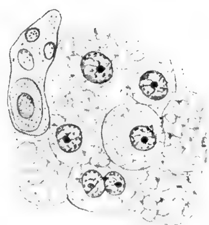


Fig. 3.

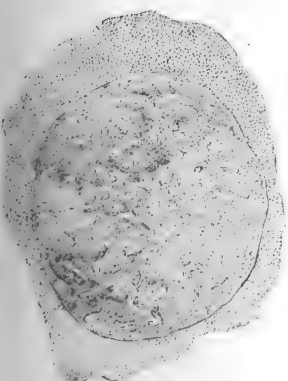


Fig. 4.

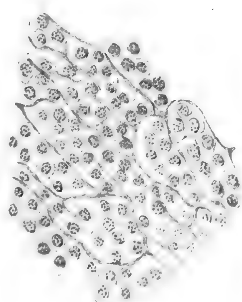


Fig. 5.

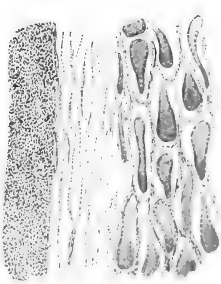
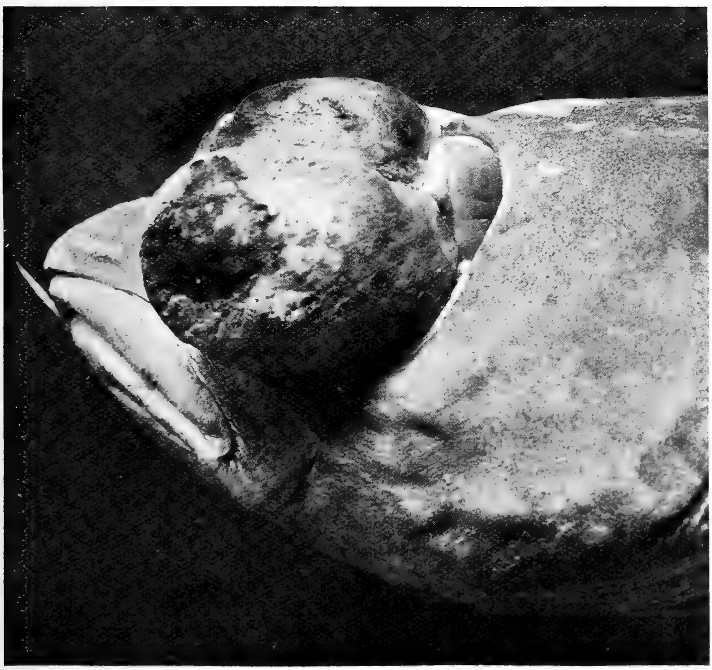


Fig. 6.

Fig. 1. Epithelioma from a Turbot.
Figs. 2, 3 and 4. Fibrosis of the liver from a Conger.
Figs. 5 and 6. Benign tumours in a Halibut.



FIBROMA IN THE ORBIT OF A COD.

REPORT ON THE PLANKTON OF THE PERIODIC AND OTHER CRUISES OF THE "JAMES FLETCHER" DURING 1913.

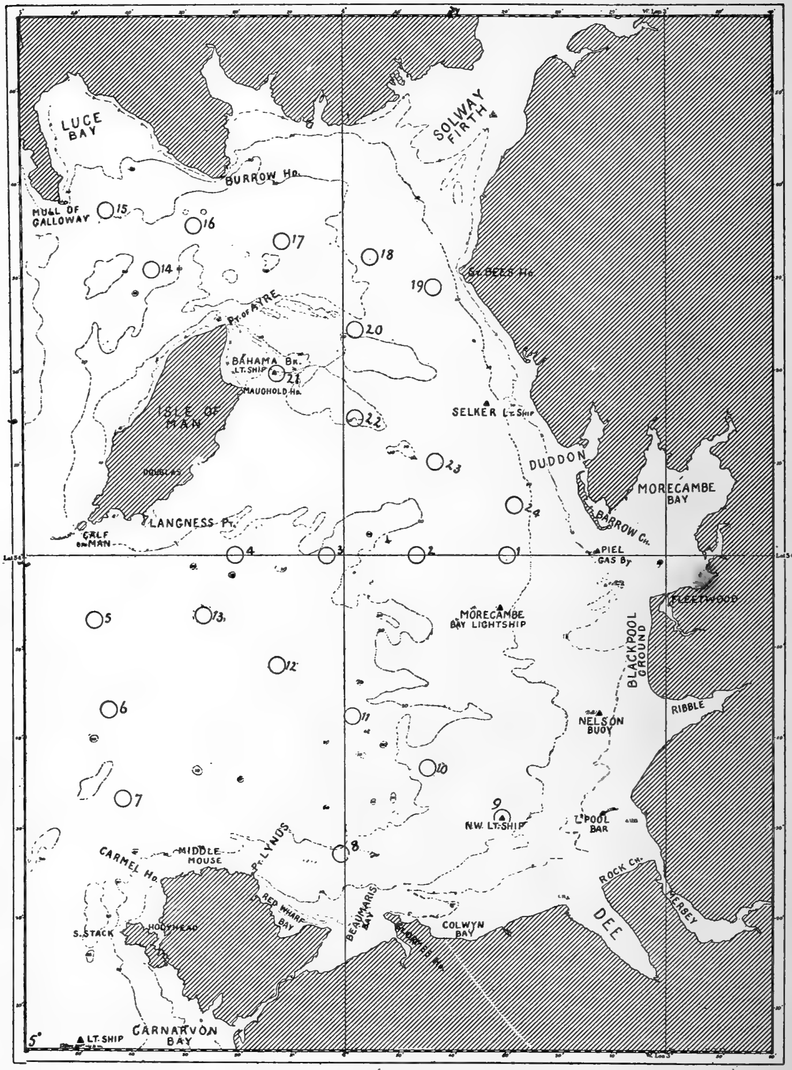
By W. Riddell, M.A.

The present report deals with all the plankton collected in the course of the work of the "James Fletcher" during the whole of the year 1913. It thus overlaps slightly the period dealt with in the Annual Report for last year, but I think it desirable to give, so far as possible, a picture of the course of events during one complete year, and the calendar year is the most convenient division.

During the year, vertical hauls were made on each monthly hydrographic cruise at Stations 5, 6, and 7, and on the quarterly cruises at Station 14 also. (See Chart, p. 146). These hauls were taken with the Nansen net (diam. 35 cms., silk number 20), each haul being from a depth of 20 fathoms to the surface. As the weather during the quarterly cruise in February, 1913, did not permit of any plankton work being done, I have included the gathering from Station 14 in February, 1914, so as to give a picture of the plankton in this region during one year.

During the year surface tow-nettings have also been taken as a matter of routine wherever the steamer was engaged in trawling. Captain Wignall and the crew of the "James Fletcher" have attended to this matter very diligently and carefully, and there are thus a large number of samples available.

Further, a few special fish-egg cruises were made during the spring, the eggs from which are being reported



Observation Stations in 1913.

on by Mr. Scott. The general plankton from these samples is also available.

Thus the collection dealt with in this report comprises about 200 samples, of which 36 are from quantitative Nansen net observations. Thirty-two of these latter represent observations at Stations 5, 6, and 7; owing to stress of weather there are no observations at these Stations in February, and none at Station 5 in March. The other four samples are from Station 14, for which February, 1914, has been included to complete the series. The results of these quantitative observations are given in Tables I and II.

The other 160 hauls cover practically the whole of the eastern half of the Irish Sea, from the south of Cardigan Bay to Luce Bay. The great majority of these are ordinary surface tow-nettings, but there are also two shear-net gatherings, and a few taken with a vertical net on the fish-egg cruises.

There is only one area which is represented throughout the year in this series, the area around Red Wharf Bay, from Great Orme's Head to Point Lynus. This series, consisting of 37 gatherings, is shown in Table III. Carnarvon Bay is represented by 16 samples, covering seven months, January, April-August, and October; these are shown in Table IV. The samples from Cardigan Bay amount to 12, covering the months of January and May-September. The area around Nelson Buoy, including the southern part of Blackpool Ground, is represented by 23 samples, covering the six months, May-October. These are shown in Table V. The other localities from which we have gatherings include Bahama Bank, Morecambe Bay Lightship, Selker Lightship, "The Hole" (25 miles W.N.W. from Piel Gas Buoy), and a few others, but for none of these have we more than a few gatherings,

10 or so at most for any locality, and they only cover a few months, while many of the samples taken on the fish-egg cruises, being taken with a specially coarse net, contain little general plankton. Hence I have not thought it necessary to give tables of the gatherings from these localities.

The course of events at Station 14 may be seen in Table I. The Diatoms show three maxima, one in May and another in October consisting mainly of *Biddulphia* and *Chaetoceras*, separated by a maximum of *Guinardia* and *Rhizosolenia* in July. The species of *Chaetoceras* in the two maxima differ; *Ch. didymum* and *Ch. teres* only occur in spring, while *Ch. debile* seems to have been more abundant in spring than in autumn. On the other hand, *Ch. boreale, Ch. contortum,* and *Ch. schuttii* only occur in autumn, while *Ch. decipiens* was more abundant in autumn than in spring. (It is hardly necessary to say that such quarterly observations as these must be used cautiously, and too much reliance must not be placed upon their records in trying to interpret the changes in the plankton.) *Eucampia* only occurs in autumn, and in fair numbers; *Ditylium* is only absent in summer, but only occurs in any quantity in autumn.

Ceratium is present throughout the year, though scarce in May. There is no very distinct maximum shown, though the rather higher numbers in October may be the end of the autumn maximum. The zooplankton is most marked in July; this is the only haul in which *Calanus* occurs in any quantity, while *Temora* is not represented in the other months.

The results of the observations at Stations 5, 6, and 7 are shown in Table II. Here the course of events appears to have been rather different. There is a well-marked *Chaetoceras* maximum in June, most conspicuous at

Station 5, accompanied by a sudden maximum of *Thalassiosira nordenskioldii* and *Nitzschia seriata.* At Station 7 the most of this maximum is due to *Lauderia, Eucampia,* and *Thalassiosira.* At Station 5 the *Rhizosolenia* maximum seems to have occurred at the same time, but at 6 and 7, it occurred later, in July, and is accompanied by *Guinardia.* It may also be noted that *Chaetoceras schuttii,* which at Station 14 occurred only in October, is here found only in April and May.

Biddulphia does not show any well-marked maximum, but was most abundant from March until May, and again from October to December.

There does not seem to be anything which could be called an autumn maximum; diatoms on the whole are scarce after July.

It is interesting to note that *Ditylium,* which is typically an autumn form, is here commonest in May and June, though at Station 14 it seems to have had more or less its normal distribution.

There is no trace in any of my samples of the sudden enormous development of *Asterionella,* which occurred at Port Erin this year.

Ceratium appears to have been commonest in June and July, but never in very great quantities. The two species, *C. longipes* and *C. intermedium,* seem to be mutually exclusive, *C. intermedium* occurring mainly in summer and autumn, *C. longipes* at the beginning and end of the year.

On the whole Station 5 seems to be the richest of the three, especially in zooplankton and *Chaetoceras.* The other diatoms, except *Thalassiosira,* are more abundant at 6 and 7, *Eucampia* and *Lauderia* especially being most abundant at 7, and also *Guinardia.*

In the Red Wharf Bay area (Table III), the course of

events seems to have been different. There is no trace of a spring maximum of diatoms, which are absent in May, June, and July. There is a distinct August maximum of *Chaetoceras* and *Rhizosolenia*, which has disappeared by October 10th. Later on *Coscinodiscus* is common, with its maximum apparently in November, while *Eucampia* is present in large quantities in October.

Ceratium shows much the same course as at Stations 5-7, especially as regard the two species *C longipes* and *C. intermedium.*

There is a well-marked zooplankton maximum at the end of July and beginning of August.

The Nelson Buoy area (Table V) shows much the same as Red Wharf Bay in regard to phytoplankton. Carnarvon Bay (Table IV) does not give much information in this respect, as diatoms, though more abundant in April and September, are never common, except one gathering of *Chaetoceras boreale* on September 17th.

Taking the district as a whole, we may make the following remarks in regard to some of the chief groups throughout the year.

Diatoms.

These were rare in January, being commonest at Stations 5-7, and are only represented generally by *Biddulphia* and *Coscinodiscus*, though *Dítylium*, *Streptotheca* and *Thalassiosira* also occur at the Nansen net stations. In February, Diatoms only occurred near Morecambe Bay Lightship, where *Biddulphia* and *Coscinodiscus* were not uncommon, and, in small numbers, about 12 miles S.E. of Bahama Bank.

In March the species were more numerous, *Bacillaria*, *Biddulphia*, *Chaetoceras*, *Coscinodiscus*, *Ditylium*, *Streptotheca*, *Thalassiosira*, &c., occurring at the Nansen net

stations, while *Asterionella, Biddulphia, Coscinodiscus, Lauderia, Nitzschia, Rhizosolenia,* and *Thalassiosira* were found near the Bahama Bank and at Morecambe Bay Ship, but in small numbers.

In April the species are still more numerous, and the numbers larger. In addition to the forms noted in the tables, *Biddulphia* and *Coscinodiscus* were not uncommon near Bahama Bank.

May, on the whole, shows a still further increase, though no diatoms were noted in Carnarvon Bay or Red Wharf Bay. In addition to the results noted in the tables, *Lauderia* was common in the south of Cardigan Bay on the 21st, while *Eucampia* and *Streptotheca* were not uncommon. *Coscinodiscus* was common in a haul on the 14th, 25 miles W.N.W. from Piel Gas Buoy. Diatoms were common at Station 14.

June, as already noted, shows the maximum at Stations 5-7, while diatoms are absent from Red Wharf Bay and rare in Carnarvon Bay. *Rhizosolenia* occurs at Nelson Buoy on the 12th, and was common 25 miles W.N.W. from Piel Buoy on the 11th. *Lauderia* also was not uncommon at the latter place.

In July, diatoms were commoner at Stations 6 and 7 than at 5, especially *Lauderia* and *Rhizosolenia.* The latter also occurred commonly at Nelson Buoy, and off St. Bees Head at the end of the month, at which time *Rhizosolenia* and *Guinardia* were common at Station 14. *Chaetoceras* occurred at Stations 6 and 7, and in a lesser degree at 5, and was also not uncommon at Nelson Buoy and at Hydrographic Station 1.

Rhizosolenia was probably not uncommon at Stations 5-7 in August, but there are no observations between July 29th and September 9th. It was abundant in this month in Red Wharf Bay, as was also *Chaetoceras,* but

only occurred once at Nelson Buoy, and then not in great quantity.

Chaetoceras boreale was common in Carnarvon Bay in September, while *Guinardia* and *Rhizosolenia* were not uncommon. The same forms, with *Coscinodiscus* and *Eucampia* were present at Nelson Buoy.

October, at Station 14, shows a fresh maximum, while at the other Nansen net stations diatoms were not abundant. The most marked feature of this month was the abundance of *Eucampia*, which was absent from Carnarvon Bay, and scarce at Stations 5-7 (except Station 7 on October 30th), but at some time or other abundant at all the inshore stations from Red Wharf Bay northwards. This form persisted on in many places well into November, and was fairly abundant at Station 7 in December. *Eucampia* is a coastal form which may be taken (according to Ostenfeld) as having a flowering period extending from spring to autumn, with a minimum in August. In our waters it was absent in spring except at Stations 5-7, while at Port Erin it was present in fair numbers in May and June, practically absent in autumn. It appears as if the representatives at Stations 5-7 in June were derived from the Manx waters, while those present at the end of the year came from our own coastal waters, each area having only one marked flowering period. Its complete absence from our Carnarvon Bay records is rather puzzling, unless we suppose that here, too, the flowering period was later than September. On the other hand it occurred in fair quantity in the south of Cardigan Bay on May 21st.

Ceratium.

This genus was present at Stations 5-7, throughout the year, being commonest in summer and autumn. In

Carnarvon Bay it is only represented twice, being common in September; elsewhere it is commonest in autumn. In the Red Wharf Bay area, as at Stations 5-7, *C. intermedium* is the summer and autumn form, and is replaced by *C. longipes* in winter and early spring. *C. tripos* occurred in small numbers in some of the Nansen net hauls in July and December, and was present in small numbers in Carnarvon Bay in January. It does not appear in any other gatherings.

NOCTILUCA.

Ostenfeld* states that though no resting stage is known, this organism probably survives unfavourable conditions in an altered state, perhaps at the bottom of the sea. It seems impossible to account for its distribution otherwise.

This year it appeared first in our records in June, at places so far apart as the north of Cardigan Bay (June 4th) and Nelson Buoy (June 12th), being fairly abundant at both places.

By July it had spread over most of the district, being present on various dates, often in quantity, in Tremadoc Bay, Carnarvon Bay, Red Wharf Bay, Liverpool Bar, Nelson Buoy, and No. 1 Hydrographic Station. On the 29th of this month it was present in enormous quantities, colouring the sea for miles along the north coast of Wales, and round the Liverpool N.W. Lightship. On this day it occurred, for the only time during the year, in the Nansen net samples, at Stations 6 and 7. It never occurred at Station 5 or at Station 14. It was still common in many parts of the district in August, and

* *Cons. Perm. Internat.*: *Résumé des Observations sur le Plankton*; 3me *partie*, 1913.

lingered on until November. The fact of its appearing at two stations so far apart as Cardigan Bay and Nelson Buoy within eight days, added to its absence from the Carnarvon Bay records at that time, and the fact that it only reached Stations 6 and 7 at the end of July, and never appeared at Station 5 or Station 14, seem to preclude any possibility of the presence of such enormous numbers being due to migration.

Siphonophora.

Muggiaea atlantica was again taken in Carnarvon Bay in small numbers towards the end of September. It was not found in other gatherings from here or from Cardigan Bay. Last year it appeared on September 12th, so that the time of its occurrence is the same in both years.

Pleurobrachia.

A large shoal of this organism seems to have visited the Lancashire coast in June and July. It first occurred in my gatherings at Nelson Buoy on June 30th, when one of two gatherings contained nothing but *Pleurobrachia* and a few decapod larvae; the other, which was a small gathering, contained more *Pleurobrachia* than anything else. Mr. Scott found it in abundance in Morecambe Bay in July, the maximum appearing about July 8th, while it was plentiful for some days before and about ten days after this date. This has the appearance of a migration from the southward, but the distribution of *Pleurobrachia* is at all times so anomalous, and it occurs under such widely varying conditions of temperature and salinity, that it is impossible to make any definite statement about its movements without a very extended series of observations.

Copepoda.

Calanus finmarchicus seems to be present in our district throughout the year, but mainly as a mid- or deep-water form. It is never common at the surface, but is often absent and generally rare. The two hauls for June 4th in Carnarvon Bay are an example of this. *Calanus* was rare in the surface gathering, but was taken in large numbers in a shear-net at a depth of about eight fathoms at the same time. In the vertical hauls the largest number recorded is 125 at Station 14 on July 30th. In the other Nansen gatherings it seems to have been most abundant at Station 5, but even here the largest numbers are 100 on July 1st, and 90 on July 29th.

Anomalocera was present in some part of the district throughout the year, though never in large numbers. It appears in our records first on January 21st, in Cardigan Bay. In February and March it was observed only at one station, 25 miles W.N.W. from Piel Gas Buoy, on February 4th and March 18th. In April it was beginning to occur more widely, being found half-way between the Selker and Bahama Lightships, as well as at the above station. From May until September it occurred occasionally throughout the whole district, gradually disappearing afterwards until in December it was only observed in Red Wharf Bay. It was never taken in the vertical nets.

Of the other Copepoda, *Pseudocalanus* is the most constant. *Temora* occurs in abundance from spring until autumn, especially in the inshore waters. *Centropages* is also common inshore at certain times, especially in summer, but is practically confined to the shallow water, being only observed once at the Nansen net stations. *Acartia* is probably the most persistent form next to

Pseudocalanus. *Isias* was present in many gatherings, and occasionally abundant. *Oithona* appears to be rare in spring, appearing in summer and persisting through autumn and winter.

Euphausiacea and Schizopoda.

I have little to add to the records I gave last year, except that this year's records enable me to extend the distribution of *Nyctiphanes couchii* in our area. In addition to Carnarvon Bay and Red Wharf Bay, in which it was noted last year, it has this year also occurred in Colwyn Bay, off Nelson Buoy, between the Selker and Bahama Lightships, at Bahama Bank, and 25 miles W.N.W. from Piel Gas Buoy. Hence it appears to be generally distributed throughout our district.

Cladocera.

Evadne and *Podon* have both been rather rare during the year. The former only occurred once in the vertical nets, at Station 5, on May 6th, the latter also once, at Station 5, on September 9th. Of the two, *Podon* was the more widely distributed. It was first observed in May, and persisted until September, being present at various times in Cardigan Bay, Carnarvon Bay, Red Wharf Bay, Mersey Estuary, and Nelson Buoy. It was never noted further North. *Evadne*, apart from Station 5, was only present in July and August. It was noted in Cardigan Bay, Mersey Estuary, and off St. Bees Head, being thus apparently more local than *Podon*.

Table I. Station 14.

Date	May 7th, 1913.	July 30th, 1913.	Oct. 30th, 1913.	Feb. 6th, 1914.
Calanus finmarchicus	2	125	6	6
Pseudocalanus elongatus	425	300	500	250
Paracalanus parvus	85	—	—	—
Acartia clausi	85	1600	100	—
Oithona similis	—	150	200	100
Temora longicornis	—	600	—	—
Nauplii	1445	8600	700	—
Balanus nauplii	340	—	—	—
Decapod larvae	1	80	—	1
Sagitta	2	50	5	6
Autolytus	—	—	—	1
Polychaet larvae	—	150	—	—
Echinoderm plutei	—	150	—	—
Lamellibranch larvae	—	—	100	—
Gastropod larvae	—	—	—	100
Medusoids	—	25	—	—
Oikopleura	—	450	—	—
Tintinnidae	170	—	1100	300
Acanthometron sp.	—	—	—	100
Dictyocha	—	—	100	—
Peridinium depressum	85	150	—	—
Ceratium furca	—	150	200	100
,, fusus	85	300	700	200
,, longipes	—	300	600	700
Actinoptychus undulatus	85	—	—	100
Asterionella japonica	85	—	100	—
Biddulphia	2000	—	2000	1300
Chaetoceras boreale	—	—	600	—
,, contortum	—	—	6500	—
,, debile	6600	—	2000	—
,, decipiens	850	—	2400	500
,, didymum	8000	—	—	—
,, schuttii	—	—	2000	—
,, teres	13000	—	—	—
,, spp.	2100	—	3600	—
Coscinodiscus concinnus	500	—	—	—
,, radiatus	500	—	300	600
Detonula schroderi	—	—	850	—
Ditylium brightwelli	250	—	2300	200
Eucampia zodiacus	—	—	36700	—
Guinardia flaccida	85	6000	1500	100
Lauderia borealis	425	—	—	200
Rhizosolenia shrubsolei	—	3400	850	—
,, stolterfothii	—	11600	—	—
Streptotheca thamensis	340	—	1700	1000
Thalassiosira gravida	425	—	—	400
Thalassiothrix nitzschioides	700	—	—	—

Table II (a).

Date	January 8th.			March 5th.		April 2nd.			May 6th.			June 3rd.			July 1st.		
Station.	5	6	7	6	7	5	6	7	5	6	7	5	6	7	5	6	7
Calanus finmarchicus	5	—	—	—	1	—	—	—	—	—	—	7	4	1	100	25	50
Pseudocalanus elongatus	150	—	—	—	—	140	10	140	85	85	85	1175	20	200	3000	—	1350
Temora longicornis	—	—	—	—	—	—	—	—	—	5	—	250	8	70	100	100	300
Centropages hamatus	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Parapontella brevicornis ...	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—
Acartia clausi..................	—	—	—	—	—	200	—	—	85	—	—	1650	—	70	2000	600	1750
Oithona similis	375	—	—	100	—	—	—	—	—	—	—	—	—	—	400	—	750
Nauplii	375	—	200	500	200	850	425	280	1300	2800	850	18300	5000	1400	8000	5400	5600
Balanus nauplii	—	—	—	—	—	70	85	200	85	—	85	—	—	—	—	—	—
Evadne nordmanni	—	—	—	—	—	—	—	—	85	—	—	—	—	—	—	—	—
Podon intermedium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Euphausid larvae	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—
Decapod larvae	—	—	—	—	—	9	1	8	4	5	—	50	2	3	25	4	14
Sagitta bipunctata	—	—	—	—	—	4	—	—	1	—	1	13	2	2	120	30	60
Tomopteris helgolandica ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	3
Polychaet larvae	75	—	—	—	—	—	—	70	—	—	85	—	—	350	—	200	100
Echinoderm plutei	—	—	—	—	—	—	—	—	—	—	—	500	—	—	—	—	—
Lamellibranch larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	26000	—	—	—
Gastropod larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Medusoid gonophores	—	—	—	—	—	1	—	—	—	1	—	500	150	—	—	50	—
Pleurobrachia pileus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	1
Tintinnidae	675	300	100	100	500	200	500	350	250	1450	850	—	—	70	—	—	—
Dictyocha fibula	—	—	—	100	—	—	85	—	—	—	—	—	—	—	—	—	—
Hexasterias sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Noctiluca miliaris	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oikopleura dioica	—	—	—	—	—	140	—	70	170	—	50	3750	300	300	1450	400	850
Pyrocystis lunula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	200	—
Dinophysis acuta	—	—	—	—	—	—	—	—	—	—	—	500	—	—	—	—	—
Peridinium spp.	—	—	—	—	—	70	—	70	170	250	85	13400	500	350	100	800	1650
Ceratium furca	225	600	500	100	200	70	350	—	250	—	—	4200	—	—	1000	600	7000
,, fusus	75	200	200	200	—	70	—	70	85	—	—	250	—	—	—	200	600
,, intermedium ...	—	—	—	—	—	—	—	—	—	—	—	700	—	—	650	2000	3000
,, longipes	225	400	600	200	—	140	250	—	85	—	—	—	—	—	—	—	—
,, tripos	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	200	100

Table II (a)—*Continued.*

Date	July 29th.			September 9th.			October 8th.			October 30th.			December 5th.		
Station.	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7
Calanus finmarchicus	90	75	30	20	65	30	5	15	8	10	12	—	3	1	—
Pseudocalanus elongatus	1650	1100	100	1000	1000	1000	700	200	300	400	300	200	100	225	150
Temora longicornis	1250	625	100	150	—	150	—	—	—	—	—	—	—	—	—
Centropages hamatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Parapontella brevicornis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Acartia clausi	3500	450	100	450	200	200	150	150	150	200	100	—	100	—	75
Oithona similis	4300	1400	—	1500	700	200	75	150	150	200	400	—	—	75	75
Nauplii	13000	5800	1750	3000	1500	1000	2500	700	900	500	400	400	100	225	300
Balanus nauplii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Evadne nordmanni	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Podon intermedium	—	—	—	150	—	—	—	—	—	—	—	—	—	—	—
Euphausid larvae	—	—	—	1	—	5	3	—	—	—	—	—	—	—	—
Decapod larvae	27	10	5	4	—	—	2	—	—	—	—	—	—	—	—
Sagitta bipunctata	50	50	20	—	—	1	—	—	1	—	2	—	1	—	—
Tomopteris helgolandica	1	4	—	—	—	—	—	—	—	—	—	—	—	—	—
Polychaet larvae	—	150	—	—	—	150	75	75	75	—	—	100	—	—	—
Echinoderm plutei	200	—	—	75	100	300	—	—	—	—	—	—	—	—	—
Lamellibranch larvae	1000	450	100	—	1100	300	300	1300	900	—	850	100	—	—	—
Gastropod larvae	—	—	—	—	—	—	—	—	—	—	100	—	—	—	—
Medusoid gonophores	25	25	5	—	—	—	2	—	—	—	1	—	—	—	—
Pleurobrachia pileus	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tintinnidae	—	—	300	450	1600	300	20000	6700	2000	300	1000	700	—	75	450
Dictyocha fibula	—	—	—	—	—	—	—	—	—	100	—	—	—	—	—
Hexasterias sp.	—	—	—	—	—	—	—	—	—	—	—	—	100	—	—
Noctiluca miliaris	—	1250	100	—	—	—	—	—	—	—	—	—	—	—	—
Oikopleura dioica	1000	—	100	150	—	225	500	—	—	100	—	—	100	—	—
Pyrocystis lunula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dinophysis acuta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peridinium spp.	2700	2200	300	75	100	75	—	—	—	—	—	—	—	75	—
Ceratium furca	1000	150	100	—	—	—	75	—	—	—	100	600	300	75	150
,, fusus	—	150	—	—	—	—	—	75	1000	—	—	1200	300	300	75
,, intermedium	4400	4200	400	225	100	—	200	75	1300	—	—	—	—	75	—
,, longipes	—	—	—	—	—	—	—	—	—	300	—	500	300	850	500
,, tripos	—	150	—	—	—	—	—	—	—	—	—	—	100	75	—

Table II (b).

Date	January 8th.			March 5th.		April 2nd.			May 6th.			June 3rd.			July 1st.		
Station.	5	6	7	6	7	5	6	7	5	6	7	5	6	7	5	6	7
Actinoptychus undulatus...	—	—	200	—	—	420	—	840	—	2400	900	—	750	—	—	—	—
Asterionella bleakleyi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, japonica	—	—	—	—	—	70	250	—	—	2300	170	4500	2000	4000	—	—	—
Bacillaria paradoxa	—	—	—	1100	2000	3200	11000	12000	1350	16750	2800	3500	10000	3750	—	—	—
Biddulphia aurita	—	—	—	—	200	—	—	—	—	—	—	—	—	—	—	—	—
,, regia	825	1350	700	9600	6600	4200	8000	12600	800	8000	2000	800	400	100	—	400	100
,, sinensis	375	—	—	—	—	400	500	800	50	1000	900	100	200	100	—	—	—
Cerataulina bergonii	—	—	—	—	—	—	—	—	—	—	85	—	—	—	—	—	—
Chaetoceras boreale	—	—	—	—	—	—	—	—	—	—	—	45000	1000	9000	300	3500	5000
,, breve	—	—	—	—	—	—	—	—	—	—	—	328000	1400	2250	—	2300	—
,, constrictum ...	—	—	—	—	—	1200	950	150	2700	—	—	90000	—	—	—	—	—
,, criophilum ...	—	—	—	—	—	—	—	—	2000	—	—	28000	—	—	—	—	—
,, debile	—	—	—	—	—	—	—	—	44500	1350	—	3150600	8800	2500	—	—	—
,, decipiens	—	—	—	—	—	6600	3400	500	8300	—	—	396500	—	1200	—	800	—
,, diadema	—	—	—	—	—	—	—	—	—	—	—	9500	—	—	—	—	—
,, schuttii	—	—	—	—	—	3500	2000	300	8000	—	—	—	—	—	—	—	—
,, teres	—	—	—	—	600	1200	—	200	18500	—	—	42500	400	600	—	—	—
,, spp.	—	—	—	—	—	—	—	—	170	—	750	8744000	45800	2500	—	—	—
Coscinodiscus concinnus ...	75	—	100	400	200	750	425	400	—	700	170	—	600	350	—	—	—
,, grani	—	—	—	—	—	300	—	70	—	—	—	—	—	—	—	—	—
,, radiatus ...	1000	1850	2000	2700	2400	2500	7000	3600	1500	5000	4000	1200	5200	1400	—	—	200
Detonula schroderi	—	—	—	—	—	—	—	—	—	—	—	2600	—	275	—	1650	—
Ditylium brightwelli.........	—	75	—	400	500	350	950	1100	1400	5000	700	2000	500	500	—	—	—
Eucampia zodiacus	—	—	—	—	400	—	—	—	2000	—	—	60000	12000	435000	—	6200	8500
Guinardia flaccida...........	—	—	—	400	—	—	250	70	850	250	—	11300	500	10000	5700	48700	252500
Lauderia borealis	—	—	—	—	—	280	420	420	2400	1300	—	7000	1000	1333000	—	—	1750
Leptocylindrus danicus ...	—	—	—	—	—	—	—	—	—	—	—	—	850	4300	—	—	—
Nitzschia seriata	—	—	—	—	—	150	900	4200	—	5700	—	3750000	2000	—	—	—	—
Rhizosolenia hebetata ...	—	—	—	—	—	—	—	—	—	—	—	132200	200	200	—	11800	36000
,, setigera	—	—	100	—	100	—	—	—	—	170	85	—	200	1400	—	—	—
,, shrubsolei ...	—	—	—	100	—	—	—	70	400	—	—	302000	350	34600	4600	70700	342500
,, stolterfothii	—	—	—	—	—	—	—	—	—	—	—	11700	300	1500	3000	18300	190000
Streptotheca thamensis ...	375	3750	3000	15600	8600	6000	14600	12000	2500	32700	11000	5200	35000	31000	—	13000	600
Thalassiosira gravida	—	1850	3700	4400	8400	1450	11400	11200	2200	13600	9500	66000	—	700	—	—	—
,, nordenskioldi	—	—	—	—	—	—	—	—	2000	800	—	27000000	27500	223000	—	800	—
Thalassiothrix nitzschioides	—	—	—	500	300	1700	8500	7000	1350	14800	700	—	5400	—	—	—	—

Table II (b)—*Continued.*

Date	July 29th.			September 9th.			October 8th.			October 30th.			December 5th.		
Station.	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7
Actinoptychus undulatus	—	—	—	—	—	—	—	—	150	—	—	—	100	—	75
Asterionella bleakleyi	—	—	—	—	—	—	—	—	—	—	—	100	—	225	—
,, japonica	—	—	—	—	—	—	150	400	200	200	400	—	300	—	—
Bacillaria paradoxa	—	—	—	—	—	—	—	—	2400	—	—	—	—	675	3200
Biddulphia aurita	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, regia	—	—	—	—	1400	200	400	700	8500	1000	2000	4000	1000	2000	5000
,, sinensis	—	—	—	—	—	—	—	—	2500	150	200	200	300	350	500
Cerataulina bergonii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chaetoceras boreale	2500	1600	500	600	—	—	300	—	150	—	—	—	—	—	—
,, breve	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, constrictum	—	—	—	—	—	—	200	—	—	1300	—	—	—	—	—
,, criophilum	—	—	—	—	—	—	—	—	—	—	—	—	200	675	—
,, debile	—	—	—	—	—	—	—	—	500	—	—	—	—	—	—
,, decipiens	—	—	400	1400	—	—	5000	—	1300	500	1350	1200	1100	2250	1300
,, diadema	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, schuttii	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, teres	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coscinodiscus concinnus	—	—	—	—	—	—	—	—	—	—	—	—	—	75	75
,, grani	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, radiatus	—	300	—	—	200	150	500	600	750	100	300	400	300	750	375
Detonula schroderi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ditylium brightwelli	—	—	—	—	—	—	—	—	75	—	100	—	500	75	75
Eucampia zodiacus	—	—	—	—	—	—	200	500	300	—	—	2300	300	2000	11500
Guinardia flaccida	200	—	2700	150	400	—	—	—	2500	200	200	3000	300	—	1000
Lauderia borealis	—	—	—	—	—	—	—	—	—	—	—	800	—	—	—
Leptocylindrus danicus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nitzschia seriata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhizosolenia hebetata	2300	1400	400	—	—	—	150	—	—	—	—	—	—	—	75
,, setigera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, shrubsolei	2700	750	2000	150	—	—	—	—	—	—	—	600	100	—	150
,, stolterfothii	9000	4000	2000	150	—	—	—	—	—	—	—	500	—	—	225
Streptotheca thamensis	—	—	200	—	100	200	1000	2500	5700	2500	2800	2500	2300	3000	5800
Thalassiosira gravida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, nordenskioldi	—	—	—	—	—	—	—	—	—	300	—	—	—	—	—
Thalassiothrix nitzschioides	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table III.

Month.	Jan.	Feb.	March.		Apr.	May.					
Day of Month.	20	26	6	6	3	15	19	20	22	29	29
Locality.	10 miles E. of Pt. Lynus.	10 miles N. of Gt. Ormes Head.	Red Wharf Bay.	10 miles E. of Pt. Lynus.	9 miles E. of Pt. Lynus.	Red Wharf Bay.	Red Wharf Bay.	Red Wharf Bay.	Near Puffin Id., Beaumaris B.	6 miles N. of Gt. Ormes Head.	Red Wharf Bay.
Calanus finmarchicus	r.	r.	r.	r.	r.		r.				
Pseudocalanus elongatus	c.	r.	r.	+	c.	c.	+	c.	c.		
Temora longicornis					c.	c.c.	c.	c.	c.	r.	+
Acartia clausi	+	r.		+	c.	c.			r.	+	c.
Centropages hamatus						c.		+	r.	r.	+
Isias clavipes						+	+			r.	
Anomalocera patersoni						r.	r.			r.r.	
Oithona similis				r.		c.					
Nauplii	r.				c.				+		
Balanus nauplii			+	r.	c.						
,, cypris						c.		r.			
Podon intermedium										+	
Meganyctiphanes norvegica											
Nyctiphanes couchii											
Euphausid larvae											
Gastrosaccus spinifer							r.				
Siriella armata											
Lamprops fasciata							r.				
Decapod larvae		r.			+	r.	r.	r.	+		r.
Oikopleura	+								c.		
Sagitta bipunctata	c.	r.	r.	+			r.	r.	r.		r.
Tomopteris helgolandica											
Autolytus prolifer	r.	r.	r.	c.	c.			r.	r.	r.	r.
Annelid larvae	r.			r.							
Lamellibranch larvae											
Gastropod larvae											
Medusoids						r.			c.		
Pleurobrachia pileus											
Noctiluca miliaris											
Ceratium furca											
,, fusus	r.										
,, intermedium											
,, longipes	r.										
Biddulphia regia	r.		r.	r.							
,, sinensis	r.r.										
Cerataulina bergonii											
Chaetoceras boreale											
,, criophilum											
,, spp.*											
Coscinodiscus concinnus					r.						
,, grani											
,, radiatus	r.										
Eucampia zodiacus											
Guinardia flaccida											
Lauderia borealis											
Rhizosolenia hebetata											
,, shrubsolei											
,, stolterfothii											
Streptotheca thamensis											
Thalassiosira gravida											

* Too broken up to be easily identified. c.c.—very common. c.—common. +—neither common nor rare. r—rare. r.r.—very rare.

Table III—*Continued.*

Month.	June.			July.		August.				Sept.	
Day of Month.	5	5	11	21	23	7	12	13	26	10	26
Locality.	Red Wharf Bay.	Off Gt. Ormes Head.	Red Wharf Bay.	Off Gt. Ormes Head.	Near Puffin Island.	Off Gt. Ormes Head.	Off Gt. Ormes Head.	Red Wharf Bay.	Red Wharf Bay.	Red Wharf Bay.	Red Wharf Bay.
Calanus finmarchicus	r.	......	......	......	......	......	r.	......	r.	r.	r.
Pseudocalanus elongatus	c.	c.	+	r.	c.c.	c.c.	c.	c.	r.	c.	c.
Temora longicornis	c.	c.	c.	+	c.c.	c.c.	c.	c.	......	+	+
Acartia clausi	c.	......	......	+	c.c.	c.c.	c.	c.	r.	c.	c.
Centropages hamatus	c.	c.	c.	+	c.c.	c.c.	c.	c.	......	c.	+
Isias clavipes	+	......	......	......	......	c.c.	+	......	......	......	......
Anomalocera patersoni	......	......	......	......	......	......	......	......	......	r.	......
Oithona similis	......	......	......	r.	c.	c.c.	c.	c.	r.	c.	c.
Nauplii	r.	c.	+	r	+	c.	c.	+	......	......	r.
Balanus nauplii	......	......	......	......	......	......	......	......	......	......	......
,, cypris	......	......	......	......	......	......	......	......	......	......	......
Podon intermedium	+	......	......	r.	+	......	......	......	......	......	r.
Meganyctiphanes norvegica	......	......	......	......	......	......	......	......	......	......	......
Nyctiphanes couchii	......	......	......	......	......	......	......	......	......	......	......
Euphausid larvae	......	......	......	......	......	......	......	......	......	......	......
Gastrosaccus spinifer	......	......	......	......	......	......	......	......	......	......	......
Siriella armata	......	......	......	......	......	......	......	......	......	......	......
Lamprops fasciata	......	......	......	......	......	......	......	......	......	......	......
Decapod larvae	+	r.	r.	r.	c.	r.	c.	r.	r.	r.	r.
Oikopleura	r.	......	+	......	......	......	......	+	+	......	......
Sagitta bipunctata	r.	r.	+	r.	+	c.	c.	c.	c.	c.	c.
Tomopteris helgolandica	......	......	r.	......	......	......	......	......	......	......	......
Autolytus prolifer	......	......	r.	......	......	......	......	......	......	......	......
Annelid larvae	......	......	r.	r.	......	+	r.	......	......	......	......
Lamellibranch larvae	......	......	......	......	......	......	......	......	......	c.	......
Gastropod larvae	......	......	......	......	......	......	......	......	......	+	......
Medusoids	......	......	......	......	r.	......	......	......	......	......	......
Pleurobrachia pileus	......	......	......	......	r.	......	......	......	......	......	......
Noctiluca miliaris	......	......	......	c.c.	c.c.	r.	+	+	c.	......	......
Ceratium furca	......	......	......	......	......	......	......	......	......	......	c.
,, fusus	......	......	......	......	......	......	......	......	+	+	c.
,, intermedium	......	......	......	......	......	r.	......	......	+	+	c.
,, longipes	......	......	......	......	......	......	......	......	......	......	......
Biddulphia regia	......	......	......	......	......	......	......	......	......	......	......
,, sinensis	......	......	......	......	......	......	......	......	......	......	......
Cerataulina bergonii	......	......	......	......	......	......	......	......	......	......	......
Chaetoceras boreale	......	......	......	......	......	......	......	......	c.c.	......	......
,, criophilum	......	......	......	......	......	......	......	......	c.c.	......	......
,, spp.*	......	......	......	......	......	......	......	......	......	......	......
Coscinodiscus concinnus	......	......	......	......	......	......	......	......	......	......	......
,, grani	......	......	......	......	......	......	......	......	......	......	+
,, radiatus	......	......	......	......	......	......	......	......	......	......	......
Eucampia zodiacus	......	......	......	......	......	......	......	......	......	......	+
Guinardia flaccida	......	......	......	......	......	......	......	......	......	......	......
Lauderia borealis	......	......	......	......	......	......	......	......	......	......	r.
Rhizosolenia hebetata	......	......	......	......	......	......	......	......	c.c.	......	r.
,, shrubsolei	......	......	......	......	......	......	......	......	c.c.	......	r.
,, stolterfothii	......	......	......	......	......	......	......	......	c.c.	......	......
Streptotheca thamensis	......	......	......	......	......	......	......	......	......	......	......
Thalassiosira gravida	......	......	......	......	......	......	......	......	......	......	......

* Too broken up to be easily identified. c.c.—very common. c.—common.
+—neither common nor rare. r—rare. r.r.—very rare.

Table III—*Continued.*

Month.	October.								November.			December.			
Day of Month.	2	8	17	18	18	22	23	28	4	4	20	5	5	13	16
Locality.	Off Gt. Ormes Head.	Red Wharf Bay.	Beaumaris Bay.	Red Wharf Bay.	Off Gt. Ormes Head.	Red Wharf Bay.	Off Gt. Ormes Head.	10 miles N.W.½N. from Gt. Ormes Hd.	Red Wharf Bay.	Beaumaris Bay.	Red Wharf Bay.	Red Wharf Bay.	Beaumaris Bay.	Beaumaris Bay.	Beaumaris Bay, Near Puffin Id.
Calanus finmarchicus								r.			r.	r.	r.r.		r.r.
Pseudocalanus elongatus	c.	c.	c.	c.	c.	c.	c.	+	c.c.	c.	c.	r.	c.	+	+
Temora longicornis	c.	+		+	c.	+	c.		c.	+					
Acartia clausi	c.	c.	c.	+	c.		c.	+		+	c.	r.	+	+	+
Centropages hamatus	c.	+		+	c.		c.		+						
Isias clavipes															
Anomalocera patersoni		r.										r.			
Oithona similis	c.	c.	c.	c.	c.	c.	c.	+	c.c.	c.	c.	r.	+	+	r.
Nauplii					r.			r.	r.		r.				
Balanus nauplii															
,, cypris															
Podon intermedium															
Meganyctiphanes norvegica											r.				
Nyctiphanes couchii											c.		r.		
Euphausid larvae										r.					
Gastrosaccus spinifer															
Siriella armata											r.				
Lamprops fasciata															
Decapod larvae	r.	r.			r.			r.		r.	r.				
Oikopleura					+	+	r.	r.							
Sagitta bipunctata	+	+	r.	+	r.	+	+	r.	+	c.	c.	r.	c.	r.	r.
Tomopteris helgolandica											r.		r.	c.	
Autolytus prolifer	+	r.					+	r.							
Annelid larvae	r.	+		+	r.	c.	c.	r.	+		+			r.	
Lamellibranch larvae					r.		r.							+	+
Gastropod larvae															
Medusoids		r.					+	r.	r.	r.					
Pleurobrachia pileus				+			r.		+						
Noctiluca miliaris						r.	r.		r.						
Ceratium furca				r.	r.	+	r.		r.						
,, fusus	+			r.	r.	+	r.								
,, intermedium	c.	c.	+	+	+	c.	c.	+							
,, longipes									+	+			r.		
Biddulphia regia	r.			r.					r.	r.	r.	r.	r.	r.	r.
,, sinensis				r.	r.r.	r.r.									
Cerataulina bergonii									r.						
Chaetoceras boreale		r.	r.												
,, criophilum															
,, spp.*	r.			r.	r.				r.						
Coscinodiscus concinnus	r.	c.	c.	+	r.	+	r.	r.	c.c.	c.	r.	r.	r.	r.	r.
,, grani	+	+	+	+	r.	r.	r.		+	+	r.	r.			
,, radiatus															
Eucampia zodiacus	+	c.	c.c.	c.	+	c.c.	r.	r.	c.	+					
Guinardia flaccida						r.									
Lauderia borealis															
Rhizosolenia hebetata									r.						
,, shrubsolei	r.	r.							r.						
,, stolterfothii															
Streptotheca thamensis													r.		
Thalassiosira gravida									r.						

* Too broken up to be easily identified. c.c.—very common. c.—common. +—neither common nor rare. r—rare. r.r.—very rare.

Table IV. Carnarvon Bay.

(The first haul on June 4th is a shear-netting from 8 fathoms deep; all the rest are surface hauls.)

Month.	Jan.	Apr.	May.				June.			July.		August.		September.		
Day of Month.	20	3	15		27		3	4		2	22	6	14	9	17	24
Calanus finmarchicus	+				r.	r.	r.	c.c.	r.	+	r.	r.	r.		r.	r.
Pseudocalanus elongatus	c.		+	c.	c.	c.	r.	+		c.	c.	c.	+	c.	c.c.	c.c.
Temora longicornis			c.	c.		c.		+		+	+		+	c.	c.	c.
Acartia clausi	+	r.			+	c.	c.		r.	c.	+	c.	+	c.	r.	c.c.
Centropages hamatus		r.	+	r.	c.	c.	+				c.	c.	+	+	c.	
Isias clavipes				r.							c.					
Anomalocera patersoni							r.		r.					r.		r.
Oithona similis	r.									+	+	c.	+	c.	c.	c.
Nauplii	+	r.	+	c.	r.	r.			r.	c.	r.	+	r.			r.
Balanus nauplii		r.		r.												r.
,, cypris				+												
Podon intermedium											r.	r.				
Nyctiphanes couchii	+															c.
Euphausid larvae								r.								
Cumacea	r.															
Decapod larvae			r.	r.	r.	r.	c.	c.		c.	+	r.	+	r.	r.	r.
Oikopleura		r.	+		+				r.	+			+	+		
Sagitta bipunctata	c.		r.	r.	+	r.	r.	+		+	+	r.	+	c.	c.	c.
Tomopteris helgolandica																c.
Autolytus prolifer	c.		r.	r.		r.	r.								r.	
Annelid larvae								r.							+	
Lamellibranch larvae															r.	
Muggiaea atlantica																r.
Medusoids				+							c.	c.	r.		+	+

Table IV—*Continued.*

Month.	Jan.	Apr.	May.				June.			July.		August.		September.		
Day of Month.	20	3	15		27		3	4		2	22	6	14	9	17	24
Pleurobrachia pileus								r.								
Noctiluca miliaris											+	c.c.	+			
Ceratium furca															c.	
,, fusus															c.	
,, intermedium															c.	
,, tripos	r.															
Asterionella bleakleyi		+														
Biddulphia regia	r.	+														
,, sinensis	r.r.	+														
Chaetoceras boreale															c.	
,, spp.									r.							
Coscinodiscus concinnus	r.	+	r.	r.												
,, grani	r.															
,, radiatus	r.	+														
Ditylium brightwelli		+														
Guinardia flaccida															+	
Lauderia borealis		+														
Rhizosolenia shrubsolei		+							r.						+	
,, stolterfothii															+	
Streptotheca thamensis		+														
Thalassiosira gravida		+														

Table V. Nelson Buoy Area.

Month.	May.					June.			July.			August.				September.				October.			
Day of Month.	9	19		26		12	30		16	21	25	5	11	15	25	16		23	30	10	14	21	24
Calanus finmarchicus																r.							
Pseudocalanus elongatus	c.		c.	+	c.	c.					r.	c.	c.	+	c.	c.	c.	c.	c.	c.	c.	c.	c.
Temora longicornis	c.	c.	c.	+	c.	+	r.		r.	+	r.	+	c.		c.			c.	+	c.			
Acartia clausi	c.	+	c.	+			r.		r.	c.		c.	c.	+	c.	c.	c.	c.	c.	c.	c.	+	
Centropages hamatus	c.c.		r.			+			r.	+		c.		+	c.		r.	c.			+	+	r.
Isias clavipes										+													
Anomalocera patersoni	r.						r.r.			+	r.r.	r.	r.		r.	r.	+					r.	
Oithona similis		r.										+	c.	+	c.	c.	c.	c.	c.	c.	c.	c.	c.
Nauplii		c.	r.	c.	+	+				+	r.											r.	
Balanus nauplii		+	c.																				
,, cypris		+																					
Podon intermedium														r.	r.	r.	r.						
Nyctiphanes couchii																						r.	
Decapod larvae	r.	r.	r.		r.		r.	r.	r.	r.	r.	r.	r.	r.	r.	r.	r.	r.	r.	r.		r.	
Oikopleura									r.					r.									r.
Sagitta bipunctata	r.	r.	r.			r.			r.	+	r.	c.	+		c.	c.	c.		c.	c.	r.	+	
Autolytus prolifer					r.r.																	+	
Annelid larvae									r.				+				r.		r.	c.	+	+	+
Lamellibranch larvae													+					c.		c.			r.
Gastropod larvae													r.							r.			
Medusoids									r.														r.
Pleurobrachia pileus							+	c.c.						r.						r.			
Noctiluca miliaris						c.			c.c.			c.	r.	+	c.	r.	+	r.	r.				r.
Ceratium furca														+	+	c.	c.	+	c.	+			
,, fusus										r.	+			+	+	c.	c.	+	c.	+	r.		
,, intermedium										+	+				+	c.	c.	+	c.	c.	c.	c.	
Bacillaria paradoxa																			+				
Biddulphia regia		r.	r.							r.										+			
,, sinensis																				+	+	r.	r.
Chaetoceras boreale										+	+								+	r.			
,, criophilum											+												
Coscinodiscus concinnus			r.																+		c.	r.	+
,, grani																			+	+	c.	r.	+
Eucampia zodiacus																			+	r.	c.	r.	c.c.
Lauderia borealis											r.												
Rhizosolenia hebetata											c.c.								+				r.
,, shrubsolei						+				c.	c.c.				+								r.
,, stolterfothii											c.c.								+				

ON THE PLAICE MEASUREMENTS MADE IN THE EASTERN WATERS OF THE IRISH SEA DURING THE YEARS 1909-1913.

By Jas. Johnstone, D.Sc.

Contents.

(1) Introduction.

The abstracts of the measurements made at sea and in the laboratory during the year 1913 are presented here in continuation of former reports, but an attempt has also been made to summarise all the data collected during the period 1909-1913. This series of investigations was initiated in 1908, with the object of providing material for a discussion of the question of which particular trawl-mesh might be generally allowed in the Lancashire and Western Sea Fisheries District, and with the adoption of a six-inch mesh for use inside the district the immediate object of the investigations was attained. In 1910, however, the scheme of work previously followed was amplified, and was adopted in 1911, when assistance from the Development Fund was obtained by the Committee. It was hoped that the amplified scheme would

provide data for an adequate study of the distribution and life-history of the plaice in the waters of the eastern side of the Irish Sea and St. George's Channel, and not merely for that of the distribution of the fish in Liverpool Bay. Unfortunately, the larger object is, so far, unattainable, and the measurements collected suffice only for the study of the plaice on the inshore fishing grounds between Blackpool and Red Wharf Bay. So far, the important fishing ground to the north-east of the Isle of Man, as well as those in Carnarvon and Cardigan Bays, are practically unstudied; while much-needed data in connection with the early life-history of the plaice is unavailable for lack of extensive plankton material. The exact range of the spawning period, and the positions of the areas frequented by spawning plaice in the Irish Sea, are still unknown, while our knowledge of the history of the pelagic and first demersal stages of the young fish is almost entirely a blank. We cannot, therefore, attempt a sketch of the life-history of the plaice in general, but it seems useful, nevertheless, that the somewhat meagre results of the investigations of the last five years should be summarised and discussed critically, in order that whatever work may be projected in the immediate future may be directed to the greatest advantage.

The results of the measurements of plaice made at sea and on board the police cutters, and those of the examination of plaice samples received at the Liverpool laboratory, are given in the series of Tables I to XV. The arrangement of these is that of former reports, so that it needs no further allusion. These results are, on the whole, less complete and satisfactory than those of 1912. They are not discussed here since those that are useful have been incorporated into the general summary of the five years' investigation. Tables XVI to XXV, which follow

those relating to the work of 1913, give the results of this summary, and in the following sections whatever of interest appears to emerge from a broad consideration of the data available is discussed.

(2) The Statistical Methods Employed.

The actual measurements made at sea on board the steamer and the police cutters are, so far as my own observation goes, reliable and careful. The fish have been measured on a board, into which a metre scale was sunk flush with the surface. The head of the fish is placed lightly against a bar at the zero of the scale, and the centimetre division into which the extremity of the tail falls is recorded. For some time a measuring board was employed into which pins were stuck opposite the tail of the fish. By counting the number of pins in each centimetre division the length frequencies were read off. It was, however, found to be quicker for one man to measure the fishes, while another made ticks in a book ruled off in centimetre columns. In this way a catch of even 2,000 plaice was very quickly dealt with. The fish were always measured as soon as caught, so that no correction is required to compensate for post-mortem shrinkage. This correction was obtained by re-measuring samples in the laboratory that had already been measured on board ship 24 hours previously, but it was found to be so small that it has been thought unnecessary to apply it.

Grouping of the measurements has been avoided in the working-up of the results. The arithmetical labour is lengthened, because of the absence of grouping, but the results are more accurate and have greater permanent value on this account. In the tables given in each year's report the results are collected for each month and fishing ground; and in the general summary which follows, the

data for the corresponding months of each of the years 1909-1913 are grouped together so as to obtain a general picture of the distribution, unaffected by annual changes over the quinquennial period in question.

In this way the fishing grounds in Luce Bay, the Lancashire inshore grounds from near Nelson Buoy to near Liverpool Bar Light Vessel, the fishing grounds off the Estuary of the Mersey, the small fish grounds (shrimping grounds) off the Mersey, and the inshore fishing grounds in and off Beaumaris, Conway, and Red Wharf Bays are dealt with here. It was hoped in 1911 that it might also be possible to study the inshore grounds in Morecambe Bay, in Menai Straits, in Carnarvon Bay, and in Cardigan Bay, and the amplified scheme of investigations prepared then included such samplings in its programme. Some catches have indeed been made, but far too few to be of any real value. The winter spawning grounds about Bahama and King William Banks were also to have been investigated, but this has not been possible. The present summary deals, then, with the plaice fishery of "Liverpool Bay" alone.

Tables XVI to XXII give the results of the measurements made at sea on these grounds. The Luce Bay samples were obtained during the years 1908 to 1912 inclusive, when the vessel was employed in obtaining spawning plaice for the Piel Hatchery. The voyages for this purpose were made in the months September to December. The Table gives, therefore, the distribution of lengths applying only to a part of the year. The plaice fishery on the inshore grounds between Nelson Buoy and Liverpool Bar is essentially a summer one, so that the months May to October are those considered. The fishery in Horse Channel, and, generally speaking, outside the Mersey Estuary is mainly a summer and autumn one.

The shrimp-fishery in the Mersey Channels proceeds throughout the whole year, and small plaice are nearly always taken here in considerable numbers. All the months of the year are represented, but the data for the summer and autumn months are not so numerous as they ought to be. This is a defect that ought to be made good, for these statistical results are of considerable interest: from them we ought to be able to trace the growth and migrations of both soles and plaice during the first two years of life. Similar data ought to be obtained from the Blackpool Closed Ground and the shrimping grounds in Morecambe Bay. Great as is the interest and importance of these fisheries, they have hardly been investigated in a really adequate manner. Finally, the plaice fishery off Great Orme's Head, in Conway, Beaumaris, and Red Wharf Bays is an autumn and winter one. It has a rather sharply-marked period, beginning sometimes in the autumn, and culminating in November to January, according to the season. I have already* referred to this fishery: it is one that ought to be very closely studied, for all the data for a complete study of fishery seasons and productivity in relation to hydrographic conditions ought to be obtained by the investigation of this area, and by a rigorously accurate collection of the statistics of fish landed from these grounds. So far as the data available go, they only *suggest* such relationships; but far more exhaustive material is required before the latter can be demonstrated in detail.

In the Summary Tables XVI to XXI the actual length-frequencies are given: these have been obtained by adding together the numbers of plaice taken in each centimetre group for the corresponding months of the five years. In addition to this, the frequencies are also

***Ann. Rept. Lancashire Sea Fish. Laby.* for 1912, pp. 133, *et seq.*

expressed as percentages of the total catches: the distributions for the various months can thus be compared, and we are enabled to superpose curves plotted from the relative frequencies, and to express the statistical constants in the same units. The percentages of frequencies have been integrated: that is, beginning with the greatest length, the percentages have been added together, each to the sum of all those referring to higher lengths, as in the following Model Table.

Mersey Estuary; 13,343 Plaice caught in trawl-nets of ½-inch mesh. January, 1909-1913.

Mean length.	Actual frequency.	Percentage frequency.	Integrated frequency.
4·5	406	2·97 (f_1)	99·90
5·5	2,586	19·38 (f_2)	96·93
6·5	2,903	21·76 (f_3)	77·55
7·5	3,018	22·62 (&c.)	55·79
8·5	2,054	15·39	33·17
9·5	896	6·72	17·78
10·5	435	3·26	11·06
11·5	415	3·11	7·80
12·5	214	1·60	4·69
13·5	173	1·30	3·09
14·5	96	0·72	1·79
15·5	75	0·56	1·07
16·5	27	0·20	0·51
17·5	25	0·19	0·31
18·5	7	0·05	0·12
19·5	6	0·04	0·07
20·5	1	0·00	0·03
21·5	2	0·01 (&c.)	0·03 (&c.)
22·5	3	0·02 (f_{19})	0·02 ($f_{21}+f_{20}+f_{19}$)
23·5	0	0·00 (f_{20})	0·00 ($f_{20}+f_{21}$)
24·5	1	0·00 (f_{21})	0·00 (f_{21})
Totals	13,343	99·90	

This has been done for all the distributions in the Summary Tables, although the integrated frequencies are not given there. A graph has also been drawn for each distribution, both for the frequency series and the integral

series. These graphs are not published except one or two intended to illustrate the methods employed.

I have made use of this method of representing the frequency distributions of the kind described in the Lancashire *Annual Report* for 1909, p. 49. It was suggested to me by my friend H. J. Buchanan-Wollaston, but it was first applied in general statistical work by A. L. Bowley (*Elements of Statistics*. p. 155, 1902), It is by far the best way of dealing with data of this kind,

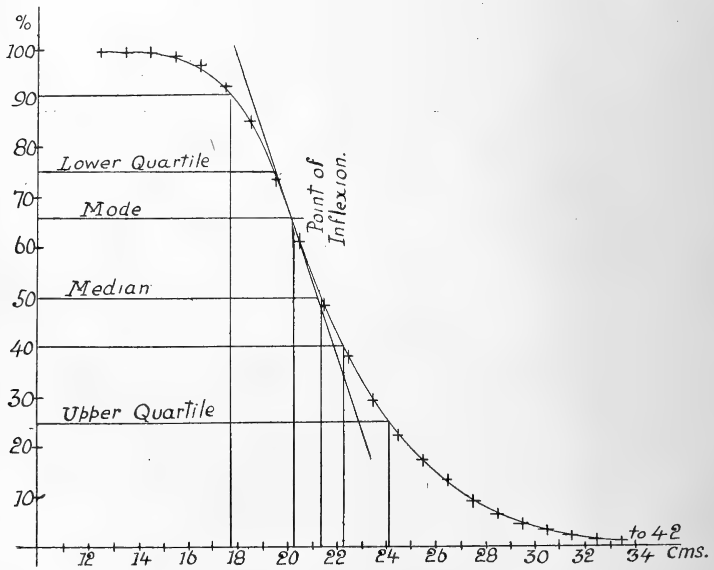


FIG. 1. Integrated length-frequencies of plaice caught on the Nelson Buoy grounds during August 1909-13. The +'s indicate the actual points plotted.

for one sees from the graphs, at a glance, the dispersion of the frequencies and the points about which the latter are concentrated. The accompanying diagram is the graph of the integrated length-frequencies of all the plaice caught in the six-inch trawl-net on the Nelson Buoy fishing grounds during the Augusts of 1909-1913. The

percentages of fish at and over each centimetre group are represented on the vertical axis and the mean lengths of each group on the horizontal axis. The curve is of the "ogive" form, so-called by Galton. We see at once that the frequencies are concentrated round a point nearer to the lower lengths than to the higher ones. The modal length, that is, the length which is the prevalent one, can be determined by inspection of the curve, for at this point the tangent crosses the curve, that is, the position of the mode is at a point of inflexion. The differential coefficient is maximal here, and $\frac{d^2y}{dx^2}$, that is, the differential coefficient of the frequency curve from which the integral curve is constructed, is at a minimum at the corresponding point, that is, the tangent is parallel to the x-axis, and the point is therefore at a cusp. This is the only convenient way of determining the position of the mode in such distributions as these, for by altering the grouping of the data we alter the apparent mode, while the work of determining the position of the mode by interpolation, or by the calculation of a theoretical probability curve is very laborious. On the other hand, if the integral curve described here is carefully drawn by means of some mechanical aid, the position of the point of inflexion can be very approximately found. A celluloid set-square on which a fine straight line is scratched is laid over the curve, so that the line crosses from one side of the latter to the other. The straight line then appears to coincide with a small segment of the curve and the two points at which the line is apparently co-incident with the curve are marked. The point of inflexion is then midway between these points, and beneath this on the x-axis is the value of the mode.

If the frequency distribution itself is irregular, this

method of integration enables us to "smooth" the data, for a curve can be more easily drawn among the points representing the integrated frequencies than among the points representing the actual frequencies themselves. The curve can then be pricked with the point of a needle where each ordinate crosses it and the corresponding point on the vertical axis read off. These latter points are percentages at and over each unit of length, and by subtracting each from the one immediately above it the original frequency series is reproduced in a "smoothed" form. Smoothing the original frequencies by taking the means of groups of three—the ordinary method—is faulty, since it assumes that the mean ordinate is equidistant from the two ordinates, and this is not the case when the curvature changes rapidly: obviously Simpson's Rule ought to be applied to find the position of the mean ordinate in the application of this method. But in the integration of the frequencies the irregularities become smoothed out since *plus* and *minus* deviations are algebraically summed.

The integral curves are used to find measures of the dispersions by graphic interpolation. The position of the point of inflexion is first marked on the curve, and vertical and horizontal lines are drawn to cut the corresponding axes: the value of the mode is the number on the horizontal axis cut by the vertical line. We may set up as a measure of the dispersion the lengths on either side of the mode between which and the mode 25 % of all the fish in the sample lie; that is, we find the lower limit of length by adding 25 to the percentage opposite to the mode, and we find the upper limit of length by subtracting 25 from the modal percentage. Horizontal lines are then drawn from these numbers on the vertical axis so as to cut the curve, and then vertical lines are drawn from the points on the curve thus obtained so as to cut the horizontal

axis. We thus find the lengths on either side of the mode within which 50 % of all the fish are placed. Thus the following graph is that drawn from the same frequency distribution graphed as an integral curve in Fig. 1. The mode is at length 20·2 cms. Two vertical lines, one drawn through length 17·8 cms., and the other through length 22·3 cms., so divide up the whole area between the curve and the horizontal axis that the area between these lines is equal to the sum of the two areas outside these lines. We see now, from this particular example, that 50 % of all the fish caught were larger than 17·8, and smaller than 22·3 cms.; 10 % were less than 17·8 cms. in length, and 40 % were greater. If desirable, we can extend the same method so as to find what percentage of the catch were contained within any two other limits of length. This is, of course, not the same thing as finding the "interquartile range," a measure of dispersion often adopted in the treatment of fishery statistics of this kind. The "interquartile range" appears to mean various things. The median value may be taken, that is, that value of the length on either side of which one-half of all the frequencies lie; then the quartiles are found, that is, those values of the length on each side of the median, between which and the median 25 % of all the frequencies lie, and between which and the extreme values of the length there are also 25 % of all the frequencies. Thus the x-axis is thus divided:—

|	25%	|	25%	|	25%	|	25%	|
lower extreme.		lower quartile.		median		upper quartile.		upper extreme.

Obviously the range of lengths (x-axis) is not simply divided into four equal parts: the median and quartiles must be found by interpolation, either from the frequencies or from a curve.

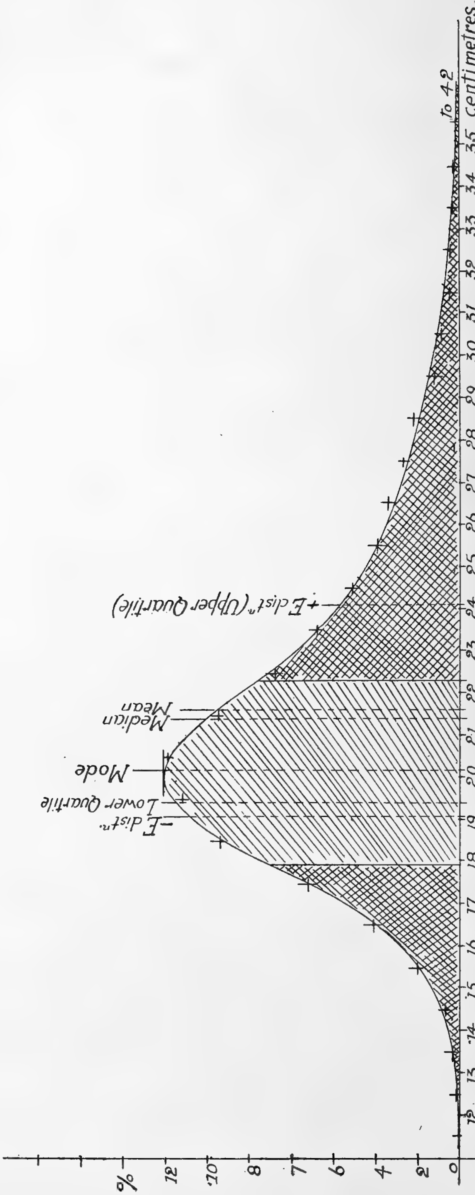


FIG. 2. Percentage length-frequencies of the plaice caught on the Nelson Buoy grounds in August 1909-13.

The + 's are the actual points plotted.

Or the mean may be calculated, and then the standard deviation, from the relations, mean = arbitrary origin *plus or minus* the first moment of the distribution according to its sign; and standard deviation = square root of the second moment of the distribution.* From the standard deviation the "probable error" of the distribution may now be calculated from the relation, probable error = $0{\cdot}6745 \sqrt{\mu_2}$. The values of the probable error are now two values, one on either side of the mean, such that there are as many observations within ordinates drawn from the x-values, as there are observations outside these ordinates. If we are dealing with a distribution which includes few observations, or which is a very irregular one, this latter method is the only convenient one of obtaining measures of dispersion or error, and the mean is the only position-value which can be employed.

The standard deviation may be regarded from two points of view—either it is simply the square root of the second moment of any frequency distribution; or it is a parameter, and can strictly be utilised only with respect to the normal curve of error. From this latter point of view it is the pair of values of x which give us the points of inflexion on the curve. It is the pair of values at which the second differential coefficient becomes zero, and in the neighbourhood of which $\frac{d^2y}{dx^2}$ changes sign, and for the normal curve of error these two values are given by $\sqrt{\mu_2}$.

But obviously we cannot regard any distribution as that represented by the normal curve of error unless we know that the causes which lead to the deviations expressed by the distribution are also those which are considered in

* The notation and methods adopted are those of W. Palin Elderton "Frequency curves and correlation."

the theory of the normal curve. The latter has a precise theoretical significance; that is, the deviations from the mean value are those very numerous, small, uncoordinated ones, as likely to cause positive as negative deviations, and the total effect of which is as likely to act in one direction as the other. This is not the case with the distributions which we have to consider in fishery statistics. The material sampled is not homogeneous, for we may have to deal with "races," or groups of fish which have different growth-rates, for instance; the samples taken do not accurately represent the natural population, and would not, however numerous they were, for the apparatus of collection—the trawl-net—selects from the population; and even if the sample taken were a truly representative one, it would not give us a symmetrical frequency distribution. The fact is that in dealing with length-frequency fishery statistics, we are not dealing with distributions expressible by the normal curve of error, nor even by any of the Pearson probability curves.

Such being the case, it seems that such conceptions as standard deviations, means, medians, and quartiles are quite artificial ones, and their use does not enable us to analyse the material studied with success. What we have really to consider is the real, "natural" form of the distributions: it is the mode and the deviations from the mode that we have to express by some figures, and not the mean or median and the deviations from these positions. The distribution graphed in Figs. 1 and 2, (Nelson Buoy, August, 1909-1913), is only a moderately asymmetrical one, other distributions may be much less symmetrical. I have shown the positions of mean, median and empirical mode in this diagram, and it will be seen that if we calculate the quartiles from the median, or the standard deviation, and the probable error from the mean, we obtain

artificial and misleading measures of dispersion. The group of fish cut out from the whole distribution lies almost entirely on the positive side of the mode (which is evidently the natural origin). They are not the plaice most characteristic of the population inhabiting this ground that we thus segregate, but plaice which are on the whole larger than the truly characteristic ones. If, on the other hand, we take 50 % of all the fish which are larger and smaller than the modal length, but as little larger or as little smaller as possible we get a natural measure of the dispersion, and a true notion of the kind of fish that are characteristic of this fishing ground. Taking either quartiles from the median, or the probable error (as deduced from the standard deviation), we find that the characteristic plaice population is one the length of which is greater than about 19 cms., and less than 24 cms. —obviously an inaccurate picture of the fish population. But taking the grouping about the mode we find that the really characteristic plaice which inhabit this ground are those which are greater in length than about $17\frac{1}{2}$ cms. and less than 22 cms. Obviously the effect of regulations (size-limits and the like) would be different as we consider one or other of these measures of dispersion.

This discussion seems rather an academic one, but it is desirable that we should express the results of the measurements made in the most natural manner. These results are, it is claimed, of considerable "practical" importance, for they are based on a large number of measurements, and they represent fairly well the condition of the Lancashire plaice grounds during the quinquennial period 1909-1913. How valuable they may be for future comparison may be appreciated when we consider how valuable a similar series of measurements made 25 years ago, when the Committee first began its work of regulation,

would now be. The question of error now arises, or rather, it will arise when an attempt is made to compare these results with similar ones made at some future time. Just how to estimate the statistical errors of the modal lengths and of the measures of dispersion adopted does not seem clear. Probably theoretical frequency distributions will have to be calculated from the rough data, and from these the errors of the modes, and the other values chosen may have to be determined. At any rate, the data obtained have been published *in extenso* for this reason.

(3) Distribution and Migration of Plaice on the Fishing Grounds.

(*a*) *Nelson Buoy to Liverpool Bar.*

We may summarise the data relative to the sizes of plaice on this fishing ground as follows:—

May: 3 % are below 15·2 cms. (6 in.); 46 % are over 19·1 cms. ($7\frac{1}{2}$ in.); 50 % are between 15·2 and 19·1 cms.

June: 9 % are below 17·3 cms. ($6\frac{3}{4}$ in.); 41 % are over 20·6 cms. (8 in.); 50 % are between 17·3 and 20·6 cms.

July: 12 % are below 18·4 cms. ($7\frac{1}{4}$ in.); 38 % are over 21·4 cms. ($8\frac{1}{2}$ in.); 50 % are between 18·4 and 21·4 cms.

August: 12 % are below 17·6 cms. (7 in.); 22 % are over 22 cms. ($8\frac{3}{4}$ in.); 50 % are between 17·6 and 22 cms.

September: 15 % are below 18 cms. (7 in.); 35 % are over 22 cms. ($8\frac{3}{4}$ in.); 50 % are between 18 and 22 cms.

October: 22 % are below 18·8 cms. ($7\frac{1}{2}$ in.); 28 % are over 25 cms. ($9\frac{3}{4}$ in.); 50 % are between 18·8 and 25 cms.

This, it will be seen, is a "small-fish" ground. About 50 % of all the plaice caught in a trawl-net of 6-inch mesh are between about 17·5 and 21·5 cms. in length.

The population on this ground is not a stationary one, a conclusion which may be deduced from the length statistics no less clearly than from the marking experiments. The modal length shows a general rise throughout the period investigated, but this increase is not a regular

Length-Frequencies of Age-Group II ♂ ♀ at Nelson Buoy, 1909-1913.

	May.	June.	July.	August.
14·5	2	1		
15·5	6	4	4	1
16·5	17	11	14	4
17·5	23	37	29	15
18·5	13	57	73	37
19·5	19	87	95	47
20·5	10	74	53	42
21·5	14	69	43	37
22·5	15	28	31	19
23·5	6	16	21	16
24·5	4	11	7	6
25·5	5	5	10	5
26·5	4	2	4	2
27·5	—	2	1	2
28·5	—	3	1	—
29·5	—	1	—	—
30·5	—	1	—	—
31·5	—	1	—	—
Mean	19·79	20·43	20·2	20·97
Error of Mean	± 0·16	± 0·19	± 0·07	± 0·09

one. If we consider only the plaice of Age-Group II, instead of all the fish caught, so as to obtain a homogeneous frequency distribution, we still find that these fish do not grow regularly, that is, although the mean length of the plaice sampled rises from 19-79 in May to 20-97 in

August, there is an apparent negative increment in July, a condition which cannot, of course, be natural. The means and the statistical errors of the means are given at the bottom of the table, and it will be seen that these means must be regarded as free from any error of significance. Now, compare this Table of the length-

Length-Frequencies of Age-Group II ♂ ♀ in Barrow Channel and Fleetwood Channel in 1909-1913.

	May.	June.	July.	September.
15·5	8	1	1	1
16·5	13	8	5	4
17·5	25	21	14	5
18·5	23	36	17	15
19·5	12	27	20	25
20·5	12	31	12	29
21·5	17	20	22	29
22·5	4	6	22	27
23·5	10	5	13	31
24·5	6	4	6	20
25·5	1	1	4	10
26·5	—	1	—	7
27·5	—	—	2	4
28·5	—	—	—	1
29·5	—	—	—	2
Mean	18·42	19·73	20·90	21·98
Error of Mean	± 0·145	± 0·10	± 0·131	± 0·121

Mean error of means = ± 0·124

Mean probable error of the difference between any two means = ± 0·175

frequencies of Age-Group II with a similar one for Barrow and Fleetwood Channels. Here we find a very regular increase in the mean length from 18-42 in May to 21-98 cms. in September. There are no data for August, but on making a graph for the series of means we can have no doubt as to the value for that month.

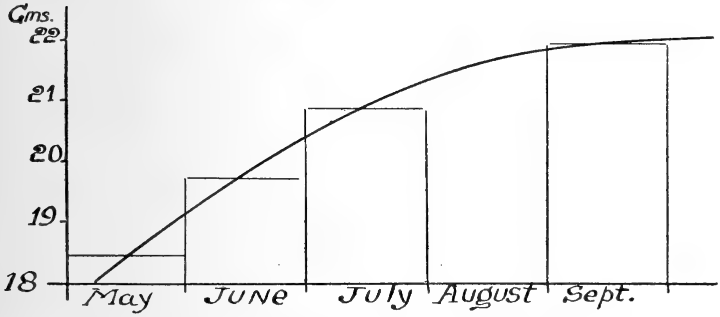


FIG. 3. Mean lengths of plaice of age-group II ♀ ♂ taken in Barrow and Fleetwood Channels in 1909-13.

As in the former Table the statistical errors of the means, and the mean error of the differences between any two means, are calculated in order to show that the means are reliable to a very considerable degree. All the evidence we have seems to show that these fishing grounds harbour a non-migratory population, which is recruited from the "nurseries" in Morecambe Bay. When food is abundant, the plaice concentrate on certain restricted parts of these fishing grounds, and when food is relatively scarce the fish are more sparsely, but more regularly distributed, but this appears to be the extent of their movements during the first three years of life. The connection between the abundance of the food and the abundance of plaice is very strikingly shown by a Table prepared by A. Scott,* which shows that plaice are relatively abundant when mussels are scarce and *vice versa*:—

1906	plaice landed	at Piel,	311	cwts;	mussels landed,	256	cwts.
1907	„	„	709	„	„	64	„
1908	„	„	2,443	„	„	85	„
1909	„	„	2,532	„	„	0	„
1910	„	„	1,184	„	„	0	„
1911	„	„	1,010	„	„	0	„
1912	„	„	778	„	„	4,313	„

* *Quarterly Report on the Scientific Work of the Lancashire and Western Sea Fisheries Committee*, October, 1913.

When large mussels are abundant plaice are scarce because of the relative scarcity of mussel fry. On the other hand, when large mussels are scarce or absent, the scars are usually stocked with very small shell-fish on which the plaice concentrate to feed. Apart from such local concentrations, the plaice population of Morecambe Bay inshore grounds is a stationary one, and such statistics as we possess show that the fish do not migrate out from the Bay until they are over three years of age. Conversely, there is little influx of fish from other grounds into the Bay, with the exception of some slight immigration from the South during the winter months.

The rate of growth shown by the Barrow Channel plaice is therefore a normal one, and is undisturbed by the immigration of fish from other grounds. When we compare the rate of growth of the Nelson Buoy plaice with that of the Morecambe fish, the only reasonable explanation of the anomalous growth-rate on the former grounds seems to be that we are dealing with a population which is being recruited from the nurseries along the Lancashire coast line from Blackpool South to the Mersey Estuary. Fish of one and two years of age migrate out during the months of April to August to the ground round Nelson Buoy, and from there towards Liverpool Bar. The conditions on the deeper grounds are presumably more favourable than they are on the nurseries—first of all, the population on the latter grounds is a much denser one; then food is probably less abundant, absolutely and relatively; and finally (as I have suggested in last year's report), the rising temperature on the nursery grounds affects the fish in some way, so that they move offshore into colder water where the natural physical conditions more nearly approach those which are optimal for fish of this range of ages. We may suppose that the growth-rate is

less on the nursery-grounds than it is on the grounds further offshore, so that successive shoals of fish arriving on the latter grounds will tend to lower the growth-rate which would be characteristic of the offshore region. If this outward migration were irregular, so that a much larger number of slowly-growing fish arrived on the grounds during July, we should have the apparent negative increment in the growth-rate that the Table shows. Altogether all the data available seem to show that the Nelson Buoy plaice fishery during the summer and autumn is one for fish that have grown up to the first, second, and third years of life on the inshore nursery-grounds, and which migrate out to sea during the months of May to July, so as to form the extensive shoals that are fished on the grounds in question.

This fishery practically comes to an end in September or October. We have practically no reliable statistics of the quantities of plaice landed monthly from these grounds—the fishery is one carried on to a very large extent by second-class sailing vessels, so that it is, so far, an almost impossible task to attempt to trace the yield of the grounds. The experimental hauls made by the "James Fletcher" indicate, however, that plaice are not at all abundant on the Nelson Buoy grounds earlier in the year than May, nor are they abundant after October. During the months of October and November the fish begin to desert these grounds, and the migration paths followed depend, to some extent, on the age of the fish. The smaller fish appear to move back inshore, where they apparently become "lost"—they probably hibernate, burrowing in the sand at the bottoms of the deeper channels in the Bays and Estuaries. From the Nelson Buoy grounds the larger plaice appear to migrate into the Ribble Estuary, into Morecambe Bay to the North, and

into the Estuaries of the Mersey and Dee to the South. The migration path most commonly followed is, however, that leading towards Red Wharf Bay to the West, and most of the large and medium-sized plaice which inhabit the Nelson Buoy grounds, and survive the summer and autumn fisheries there doubtless form part of the shoals which appear off the coasts of Anglesey and Carnarvon during the last months of the year. The plaice-marking experiments show this very clearly—even the meagre records of single experiments, such as those of last year, summarised in the present Report—show it, and the evidence becomes convincing when we deal with groups of experiments carried out under similar conditions. This, then, is the fate of the majority of the survivors of the summer and autumn Nelson Buoy plaice fishery—they migrate to the westward to risk the winter fishery there. But in most of the experiments a few plaice have been recaught about the end and the beginning of the year on the banks near the north-east of the Isle of Man. These are generally the larger plaice, and this migration is a spawning one.

Both the migration from Nelson Buoy towards Red Wharf Bay, and that towards Bahama Bank are, like the offshore migration from the nurseries to the Nelson Buoy grounds, compensatory movements the effect of which is to cause the fish to inhabit water of as nearly as possible the same physical conditions. The migration outwards from the nurseries is one from warmer water, rising in temperature, into colder water; and those from Nelson Buoy towards Bahama Bank and towards Red Wharf Bay are migrations from colder water, falling in temperature into warmer water. It is by reference to such compensatory migrations, the effect of which is to preserve as nearly as possible the optimal conditions, that we must

seek to explain the connection between the movements of fishes and changes in the hydrographical conditions.

(*b*) *Mersey Shrimping Grounds.*

These grounds, the channels and "gutters" through the banks lying outside the Estuary proper, and the shallow water margins of the banks themselves, constitute a nursery for plaice and other small fishes, and it is from this point of view that they derive their interest. But we find in much the same region very extensive "small-fish" grounds; the larger channels, Rock Channel, Horse Channel, &c., and the shallow water off the banks, harbour plaice of sizes varying, for the most part, between 18 cms. and 30 cms. There are frequent migrations of plaice from one part of the Mersey grounds to other parts, and catches made with the small-meshed net used in the shrimp trawls frequently sample shoals of fish of the larger sizes. On this account the interpretation of the statistical data is sometimes very difficult.

The catches made by means of the shrimp-trawl nets are summarised in Tables XIX-XX. They are, as a rule, large, and with some exceptions they provide us with a fair picture of the distribution of the smaller plaice in the Mersey Area. The exceptional months are May, June, and August, and the figures seem to show that the nets were fishing among shoals of plaice of the larger sizes. The numbers caught during these months are also rather small, and we may, therefore, regard the results as anomalous and likely to be modified to a large extent by further experiments.

The modal lengths of the plaice caught are given in Table XXIV. The results for the winter months, November to March, inclusive, are all very similar; at this time of year the great majority of plaice caught in

the shrimp trawls vary in modal length between 7 and 8·5 cms. The dispersion is very small.

After March, the composition of the catches becomes more complex, and we are able, to some extent, to see in the figures the influence of the three age-groups of which the plaice population on a "nursery-ground" is made up. In April, the frequency curve becomes bi-modal, and there are cusps at about 7 and 14 cms., that is, age groups O and I are represented in the catch in nearly equal proportions. The May and June figures are unreliable, but in July the first three age-groups are clearly represented since there are very distinct modes at 5·3, 11·6, and 19·4 cms. The 5·3 cms. cusp obviously represents age-group O, that is, the plaice born in the same year, and which have attained this length during the interval March-July. The 11·6 cusp represents age-group I, that is, the plaice born the previous year, and which have completed about one and a half seasons of growth, while the 19·4 cms. cusp is that formed by age-group II, fish of $2\frac{1}{2}$ years of age. In September and October, age-groups O and I are represented by the modes at 7·7 and 7·3 cms., and those at 15·6 and 13 cms. Plaice have now completed their season's growth, and Group O shows the modal length of about 7 cms. Group I has, doubtless, a modal length of about 13 to 14 cms., but the precise position of the cusp representing this yearly group in a complex curve is certainly affected by the fishing action of the net, and we cannot be sure that the sample is a representative one so far as fish of this age are concerned.

Plaice of less than 3 cms. in length are hardly ever caught in the shrimp-trawl net, and, indeed, their habitat does not seem to be that of the fish of lengths near to 7 cms. They are, however, present in great numbers in the very shallowest water near the shore, and they may

be caught easily in the sand-pools left by the receding tide. These little plaice, at the end of May or the beginning of June are about 1-2 cms. in length on the sandy beaches in the Mersey Estuary. They, and other Pleuronectid fishes of about the same age, feed greedily here on copepods—mainly *Temora*, so that occasionally 50 to 100 of these micro-crustacea may be found in the stomach of a single fish, and at this age it is often the case that the larvae of an Appendiculate Trematode may also be found among the copepods. When they are a little larger copepods are not so commonly found in their stomachs, but Polychaet larvae become very common, and occasionally larval shrimps may also be found. Sometimes (on other parts of the Lancashire coast) larval Gastropods (probably the larvae of *Littorina*), and very small shell cockles (not larvae) may be found, and, indeed, the fish appear to take whatever organisms are most abundant, and easily captured. Copepods, however, seem to be the main food of the smallest demersal stages of plaice, and other Pleuronectids, in most parts of the Lancashire District.

(*c*) *The Horse Channel Grounds.*

These include the offshore part of the Mersey Estuary extending from about the Liverpool Bar Light Vessel, along the outer edge of the Banks into Horse Channel proper, and then over towards the entrance to the Estuary of the Dee. The catches made on these grounds have all been summarised in Table XVIII, but those catches made in Rock Channel and in Crosby, Formby, or Queen's Channels are not so included. These latter grounds harbour smaller plaice than are found more offshore.

The fish caught here resemble, in their range of lengths, those caught on the Nelson Buoy grounds. Their lengths may be summarised as follows:—

April.—Under 18·1 cms. (7 in.) 10 %; over 20·9 cms. ($7\frac{3}{4}$ in.) 40 %; between 18·1 and 20·9 cms. 50 %.

May.—Under 18·4 cms. ($7\frac{1}{4}$ in.) 17·5 %; over 21·4 cms. ($8\frac{1}{2}$ in.) 32·5 %; between 18·4 and 21·4 cms. 50 %.

June.—Under 17·3 cms. ($6\frac{3}{4}$ in.) 15 %; over 20·2 cms. (8 in.) 35 %; between 17·3 and 20·2 cms. 50 %.

July.—Under 18·6 cms. ($7\frac{1}{4}$ in.) 18 %; over 21·5 cms. ($8\frac{1}{2}$ in.) 32·5 %; between 18·6 and 21·5 cms. 50 %.

August.—Under 19·3 cms. ($7\frac{1}{2}$ in.) 15 %; over 23·6 cms. ($9\frac{1}{4}$ in.) 35 % between 19·3 and 23·6 cms. 50 %.

September.—Under 19·3 cms. ($7\frac{1}{2}$ in.) 15 %; over 23·8 cms. ($9\frac{1}{2}$ in.) 35 %; between 19·3 and 23·8 cms. 50 %.

October.—Under 18·7 cms. ($7\frac{1}{2}$ in.) 10 %; over 23·3 cms. ($9\frac{1}{4}$ in.) 40 %; between 18·7 and 23·3 cms. 50 %.

The length distribution on these grounds resembles, in general, that on the Nelson Buoy grounds further North. The fish are, on the whole, a little larger: the mode varies between 19·6 and 21 cms., the average being about 20 cms., and the range over which 50 % of all the fish, distributed equally on either side of the mode, are caught is a little nearer to the larger end of the distribution than in the case of the Nelson Buoy grounds. Otherwise we have to deal with a typical small-plaice ground. It is also a ground which is not recruited from other grounds harbouring a plaice population of the same class, but one which receives its fish from the nurseries in its immediate vicinity, that is, from the shallow water grounds in the Estuaries of the Mersey and Dee. It is not a stationary plaice population that we find here, but one which arrives in successive shoals from other more inshore regions where the rate of growth of the fish is less. This is shown by the following Table:—

Length-Frequencies of Age-Group II ♂ ♀ in the Mersey Estuary, 1909-1913.

	May.	June.	July.	August.	September.
14·5	—	3	—	—	—
15·5	4	20	5	—	—
16·5	2	28	13	—	—
17·5	8	35	16	4	—
18·5	6	49	23	5	1
19·5	32	46	44	12	—
20·5	43	23	39	11	1
21·5	24	17	33	13	3
22·5	13	4	38	14	3
23·5	10	3	14	14	3
24·5	3	—	14	7	3
25·5	2	—	6	1	2
26·5	—	—	—	—	1
27·5	—	—	2	—	2
28·5	—	—	2	—	—
Mean ...	20·46	18·54	19·29	21·51	23·56
Error of Mean	±0·105	±0·08	±0·105	±0·148	±0·355

From this we find that the growth rate is apparently very irregular, dropping from May to June, and then rising. This means, of course, that the normal growth rate of an already existing population in May is partially swamped by a great influx of fish in June, and that these fish are smaller than those already present since they have been living under less favourable conditions.

(*d*) *The Plaice Fishery in Beaumaris and Red Wharf Bays.*

This is a fishery of rather a different kind from that near Nelson Buoy and off the Estuary of the Mersey. The latter are grounds which depend for their stock of fish on the stock present in the nurseries inshore from them, that is, in the Dee, Mersey, Ribble, and in Morecambe Bay. This is also the case, but to a much less extent, with the plaice fishery offshore from Great Orme's Head and Point Lynus, for while there are, doubtless, nursery

grounds in Menai Straits and in the shallow water immediately offshore from this area, these only contribute a part of the plaice population forming the material for the fishery offshore from them. A study of the statistical data of this Report, as well as that of the marking experiments, will show that this stock of fish is derived to a considerable extent from that present on the grounds to the North-East during the few months prior to the date of the fishery.

Thus the fishery is mainly an autumn and winter one. Plaice are (commercially) absent from these grounds during the months of March, April, May, and June. A certain amount of fish are taken during July, August, and September, but this is small, and it would probably be found from a careful study of the Board of Agriculture and Fisheries "D_2" form that the plaice in these months were caught in and about "Channel Course," that is, anywhere between Point Lynus and Liverpool North-West Light Vessel. About October the fishery begins to be a commercially productive one, and from this month until January, the plaice are mainly caught between Colwyn Bay and Red Wharf Bay. There are well-marked differences from year to year in the mean positions of the grounds from which the bulk of the fish are taken, and even a study of the results of the fish-marking experiments in this and former Reports will show that sometimes the main fishery lies offshore from Great Orme's Head, while in other years it is concentrated in Red Wharf Bay, or is scattered over the deeper grounds offshore from this Bay down towards the 20-fathom contour line.

About the end of the year the fishery ceases. The precise date of its commercial cessation varies from year to year, sometimes, as in 1912, it began to fall off in November, in other years, as in 1909, it only began to

fall off in February. This relatively sharp drop in the fishing may be partly artificial. The vessels which exploit these grounds are mostly smacks, and their crews appear to like to stop fishing during the Christmas week. A spell of very bad weather, N.W. to N. winds, will also put a stop to trawling here. But allowing for these "accidental" conditions, it seems to be the case that the plaice actually desert the grounds off Carnarvon and Anglesey some time between November and February. The fishery ceases rather sharply, as will be seen from the figures published by me in last year's Annual Report, pp. 136 *et seq.* It is not at all like the gradual decline in average catch that we might expect to get when a naturally-occurring fish population is being "fished-out." In a week or two, as in 1910, the average catch per day's fishing may drop from about 7 cwts. to less than 1 cwt. It seems to be certainly the case that some time about the end of the year the plaice migrate away from the Beaumaris-Red Wharf Bay area. It cannot be too often pointed out that here we have the best possible opportunity for a successful study of the relation between the productivity of a fishery and the physical conditions in the surrounding sea-area. I have tried to indicate what this possible relation is in a former Report,* but, unfortunately, the data available are insufficient for the demonstration of close relationships.

The length-measurements for this fishing ground may be summarised as follows:—

June.—Under 17·2 cms. ($6\frac{3}{4}$ in.) 5 %; over 21·6 cms. ($8\frac{1}{2}$ in.) 45 %; between 17·2 cms. and 21·6 cms. 50 %.

* 'Hydrographic Investigations and the Fisheries of the Irish Sea.' *Ann. Rept. Lancashire Laboratory* for 1912, pp. 99 to 150, 1913.

July.—Under 18·8 cms. ($7\frac{1}{2}$ in.) 15 %; over 22·6 cms. (9 in.) 35 %; between 18·8 and 22·6 cms. 50 %.

August.—Under 18·4 cms. ($7\frac{1}{4}$ in.) 10 %; over 22 cms. ($8\frac{3}{4}$ in.) 40 %; between 18·4 and 22 cms. 50 %.

September.—Under 19 cms. ($7\frac{1}{2}$ in.) 23 %; over 26·3 cms. ($10\frac{1}{2}$ in.) 27 %; between 19 and 26·3 cms. 50 %.

October.—Under 18·3 cms. ($7\frac{1}{4}$ in.) 33·5 %; over 25·8 cms. ($10\frac{1}{4}$ in.) 16·5 %; between 18·3 and 25·8 cms. 50 %.

November.—Under 19·7 cms. ($7\frac{3}{4}$ in.) 10 %; over 28·4 cms. ($11\frac{1}{4}$ in.) 27 %; between 19·7 and 28·4 cms. 50 %.

December.—Under 19 cms. ($7\frac{1}{2}$ in.) 10 %; over 25·4 cms. (10 in.) 40 %; between 19 and 25·4 cms. 50 %.

January.—Under 20·7 cms. (8 in.) 24 %; over 29·8 cms. ($11\frac{3}{4}$ in.) 26 %; between 20·7 and 29·8 cms. 50 %.

Now, if we compare this summary with those relating to the other grounds (see Table XXVI) we see that the half of all the fish taken lie between mean lengths of about 18·8 and 25·2 cms., when these fish are taken from the immediate neighbourhood of the modes (or of the means when the distributions are bi-modal). The mean range of the fish of this group is, therefore, nearly twice that of the corresponding ranges in the cases of the other two fisheries. This is not due alone to the greater modal (or mean) values of the distributions, for the mean modal-mean length for the Beaumaris-Red Wharf grounds is at 21·8 cms., while that for the Mersey offshore ground is at 20·3, and that for the Nelson Buoy ground at 19·5 cms. What we see in the North Wales fishery is a plaice popula-

tion *with a much greater range of dispersion*—in other words, the medium and large plaice are relatively more abundant than they are on the other grounds.

A notable feature of these distributions is also the presence of double modes in most of the curves formed from them. In June, July, and August the curves have single modes, that is, the population has, so far, been one which is nearly stationary except so far as it is being recruited from the nursery grounds close inshore. This modal length—19·5 to about 20·5—approximates closely to that of the other fishing grounds, and the increase is that due to the natural growth of the fish during the season June to August. The amount of growth is rather small, but we see from Table XXV that the value of the length-weight coefficient k on this ground is significantly less than it is on the Lancashire and Cheshire grounds, that is, the fish are not in such good "condition," and are presumably growing less rapidly. From October onwards, the curves become bi-modal, and the mean values of the mode for these latter months are about 19 and 28. Clearly we have an extensive immigration of plaice into the Beaumaris-Red Wharf area from the grounds to the North-East, and this consists of the larger fish from the latter regions. This immigration establishes a heterogeneous population, which is indicated by the double modes of the distributions for these months. The lower mode is that typical of the native population of the grounds, while the higher one is that of the immigrant population from the other fishing grounds. The immigration can clearly be traced in the figures for October. The curve becomes uni-modal, and the proportion of fish below the mode greatly increases—smaller fish are pouring into the area.

This migration into the Red Wharf Bay area is

indicated very clearly by the results of the fish-marking experiments. We see that in all cases where plaice have been marked and liberated on the grounds near Nelson Buoy a large proportion of the fishes recaught have been taken from the vicinity of the place of liberation. A certain proportion also migrate in the winter to the channels, and close inshore in the Bays and Estuaries, and another fraction of the fish invariably migrate into Red Wharf Bay and the adjacent grounds towards the end of the year. The mean length of the plaice liberated at Nelson Buoy in 1912-3, and recovered in the Red Wharf Bay area at the end of the same year of liberation was 25·5 cms., while the mean length of the other fish recaptured on the Nelson Buoy Grounds during the summer and autumn season there was 23 cms. Again, the mean length of the fish recaptured from the same experiments, and which had migrated during the winter months into the shallow waters inshore in the Lancashire Estuaries and Bays, was 22 cms. Now, these figures do not go very far—though a close analysis, in this way, of the results of all the experiments would probably make the evidence better—but so far as they go they tend to show that the plaice behave, to some extent, according to their age. The larger ones migrate at the end of the year to the North Wales ground, while the smaller ones return to the Estuaries from which they originally migrated to the Nelson Buoy grounds.

There can be little doubt as to what becomes of the plaice which inhabit the Beaumaris-Red Wharf grounds during the winter months, and which then disappear at the end or the beginning of the year. Some of these fish —the smaller sizes chiefly—probably migrate back again into the shallow water bays and channels between Anglesey and Morecambe Bay, and remain there during

the winter and spring months to emigrate out again into one or other of the fishing grounds during the following summer and autumn. But the larger plaice leave the Irish Sea altogether, and migrate into Carnarvon and Cardigan Bays, and even into St. George's Channel as far South as the south-west coast of Ireland. Recaptures indicating these migration paths are recorded in the Reports on the fish-marking experiments, and I have published a chart* which shows to what an extent this emigration of plaice from Liverpool Bay into Carnarvon and Cardigan Bays has been demonstrated.† So far as they go the results of the plaice measurements also confirm this opinion. As a rule the plaice captured in the southern grounds in Cardigan Bay—off Llanon and New Quay Head, for instance, are large fish: thus the mean length of one haul recorded in January, 1911, just as the plaice-emigration from Red Wharf Bay was taking place, was 32 cms. The plaice measurements in Carnarvon and Cardigan Bays are lamentably few, and although such work was contemplated in the scheme of 1911, it has not been carried out. But so far as the few observations made on the "James Fletcher" by Captain Wignall go, they tend to show that the large plaice population in Cardigan Bay is not altogether a native one, but is recruited from the larger fish moving to the South, out from Red Wharf Bay, at the beginning of the year. It is also highly probable that this is a real spawning migration on the part of the larger plaice, and that, as a rule, the bulk of the eggs which replenish the nurseries on the Lancashire, Cheshire, and North Wales coasts have been drifted up from St. George's Channel.

* 'General Summary of the results of the Plaice-Marking Experiments carried out during the years 1904-1909.' *Ann. Rept. Lancashire Sea-Fish. Laby.* for 1910, pp. 153-190. Charts I-VI. 1911.

† The contrary movement, that of Plaice from Carnarvon and Cardigan Bays into Liverpool Bay, is represented by some very exceptional results.

(*e*) *The Luce Bay Fishery.*

Luce Bay is, of course, within the area of jurisdiction of the Fishery Board for Scotland, and we have only investigated it to the extent that observations have been made while we were trawling there* for spawning plaice for the Piel Hatchery. All the plaice caught, 7,748 in all, during the years 1908, 1909, 1910, 1911, and 1912, were measured, and Table XVI gives these frequencies. These records are probably of considerable value since they show the distribution of lengths on a natural plaice ground which is closed against trawling by any kind of vessel, and which is, therefore, exploited by fishermen only to a relatively restricted extent. All the hauls, which were made during the months of September and December, are grouped together. It will be seen that the distribution is remarkably asymmetrical: had small-meshed nets been also employed, it would have been still more asymmetrical. The total range is from 10·5 to 63 cms.; the mean is at 26·8 cms., and about 28 % of all the fish are less than 21·3 cms. ($8\frac{1}{2}$ in.), about 24 % being over 34·2 cms. ($13\frac{1}{2}$ in.); 50% lie within the limits 21·3 and 34·2 cms. The dispersion is, therefore, very much greater than that of any other plaice length-distribution studied by us.

The Luce Bay area would well repay investigation on a far more extensive scale than we have yet been able to undertake. It is probable that it is an area which is, to a limited extent, populated by plaice actually reared there, that is, it contains "nursery grounds." Marking experiments have been carried out in Luce Bay, though on a rather inadequate scale, some 300 plaice in all having been dealt with. The recaptures have been few (about 45 in all), but so far as they go the results are consistent

* With the permission of the Scottish Fishery Board.

with what we otherwise know about the ground. Most of the recaptures have been made in the Bay itself by fishermen using "set-nets" and gill-nets, but a certain number of plaice have been recaptured in the Solway Firth, off the east coast of Ireland, in the Firth of Clyde, and in the Irish Sea, between the Isle of Man and the coast of Cumberland. The fish recaught in Luce Bay and in the Solway resemble in length those about the principal modal length of the whole population, that is, about 21 cms. Those taken in the Firth of Clyde were, on the average, about 35 cms. long, those recaught on the grounds between the Isle of Man and the English coast were about 31 cms., while two fish recaught off the east coast of Ireland were 32 and 39 cms. in length. What we have to deal with is, therefore, a migration of the larger fishes out from the Bay in order to spawn, and a general migration of the smaller fish between the Bay and the Solway Firth Area.

The frequency curve representing the lengths of the plaice caught shows three distinct modes, one principal mode at about 21 cms., one at 34 cms., and a less distinct one at 30 cms. It is, of course, improbable that we can apply Petersen's method to the interpretation of these frequencies. The mode at 21 cms. may probably represent the modal length of plaice of Age-Group II, the one forming the greater part of the fish population, but if the other modes at 30 and 34 cms. represent age-groups, we should have to suppose that one is concealed by the irregularities of the statistics, and is probably at about length 25 cms. We have to wait, however, for a detailed investigation of the groups by means of the examination of the otoliths before we can venture to assign lengths to the various groups. The investigation would be a most interesting one, for certain things suggest that the plaice

in Luce Bay form a group varying "racially" from that of the Irish Sea, and that the growth-rate may be a slightly different one. But to demonstrate this biometrical examination of certain selected morphological characters both in Irish Sea and Luce Bay plaice would be necessary.

(4) Growth and Age-Groups.

About 16,000 plaice have been examined in the laboratory during the years 1909-1913. As a rule, these fish were received in samples of about 100 specimens. On receipt, they were at once sorted into centimetre groups, all the fish in each group being put into wooden trays. The contents of each tray were then weighed to the nearest gram, and the average weight of the fish in each group—that is, the fish with a mean length of *n*-5 cms. was calculated. The fish were then examined for age and sex. Sex was determined by holding up each fish against a strong light with the coloured side turned towards the observer: only very infrequently was it necessary to make a dissection. The otoliths were then taken out and "read," and the age-groups recorded. In the case of plaice of less than 15 cms. in length, the sex was not, as a rule, determined. When the sample was a large one, these small fishes were sorted as usual, and then all the otoliths were placed in groups on a piece of black cardboard, and allowed to dry, so that they became attached. The cards were then placed in weak glycerine, so that the otoliths became slightly translucent, when the age-groups were read, usually with the assistance of a hand-lens.

It has been assumed that the method of age-determination by inspection of the otoliths gives reliable results. The matter is not, however, so simple as it appears, and there are perhaps some details with regard to which investigation is necessary. The statistical method used by

Einar Lea with regard to the scales of the herring, and which has been criticised by Miss Rosa Lee,* has not been employed, so that it seems likely that the results of this investigation may be relied upon.

All the plaice examined have been reported upon in former papers in these Reports. We may consider, first of all, those fish which were caught during the months of October to March, both included. These are they which had ceased to grow—for taking into account all the evidence available from these measurements, and from the results of the marking experiments, it seems highly probable that growth proceeds only during the months April to September, and is considerable only during May, June, and July. In considering the Tables XXII-III, it must, therefore, be borne in mind that we are supposing that the plaice in question are those caught at the middle of the season of no growth—that is, at the end of December. The error of age is, therefore, *plus* or *minus* three months. But since plaice do not grow during the months October to March, and since we may assume (in the meantime, at least) that the mean spawning period is about the end of March, it would appear that the mean or modal lengths deduced from Tables XXII and XXIII represent the lengths of the fish in each age-group at the end of each complete year of life.

Table XXIII then gives the numbers (actual numbers and percentages in each grouping) of those plaice in which both sex and age have been determined. Table XXII gives similar data for *all* the plaice examined, including those in which the sex was not ascertained: in this Table the sexes are grouped together. It is doubtful whether it is worth

* "An investigation into the methods of growth determination in Fishes." *Publications de Circonstance. Cons. Perm. Internat. Explor. de la Mer.* No. 63, Nov., 1912.

while discriminating between the sexes of Irish Sea plaice up to Age-Group III. Thus the mean length of male fish of Group II is 21·03 cms., while that of females of the same mean age is 21·26, a mean difference of 0·23 cms. Now small as this difference is, it is significant, for the number examined is large. Thus the standard deviations ($\sqrt{\mu_2}$) for the males and females of this group are $\pm$ 3·11 and $\pm$ 2·87 respectively, and the corresponding "probable errors" of these means ($0{\cdot}6745 \frac{\sqrt{\mu_2}}{\sqrt{N}}$, μ_2 being the "second moment" of the group frequency distributions, and N the numbers of specimens) are $\pm$ 0·052 and $\pm$ 0·05 cm., so that the probable error of the difference of the two means ($\sqrt{(E_1)^2 + (E_2)^2}$, E_1 and E_2 being the probable errors) is only $\pm$ 0·022 cm., thus being very much less than the observed difference. The difference of the mean lengths of the fish in Group III is also very small—the figures are 29·69 for the males and 26·58 for the females—and it is in the opposite direction, the males being apparently slightly longer than the females of the same mean length. But we find, on calculating the probable error, that it is greater than the observed difference in the means, so that the number of plaice examined is not great enough to yield satisfactory determinations of the mean lengths of the sexes. This, obviously, is also the case with the fish of Group IV. We may conclude, then, that the differences between the mean lengths, or growth rates, of plaice up to the end of the fourth complete year of age is small, and need not be regarded as of practical importance.

This being so, we can combine the sexes and thus obtain as large series of figures as possible, in the hope that satisfactory frequency distributions for each of the age-groups may be obtained. In this way the series of

curves in Fig. 4 has been obtained: the figure is really the graph of Table XXII, with some modifications suggested by a critical survey of the data. The heavy, continuous lines are the graphs of the series for Age-Groups O, II, III, and IV, as they are set out in Table XXII. The graph for Group I, on the other hand, is constructed from the following series of measurements:

Mean length.	No.	%
6·5	4	0·71
7·5	13	2·30
8·5	8	1·42
9·5	11	1·95
10·5	25	4·42
11·5	65	11·50
12·5	82	14·52
13·5	63	11·15
14·5	50	8·85
15·5	51	9·03
16·5	47	8·32
17·5	61	10·80
18·5	51	9·03
19·5	22	3·89
20·5	7	1·24
21·5	3	0·53
22·5	2	0·35
Totals...............	565	100·01

It will be obvious, from a consideration of Table XXII that the means of Groups I and II lie very closely together (about 18 and 20 cms.). Now the difference between the mean length of Group O and that of I is considerable, and so also is the corresponding difference between II and III, and III and IV. Why, then, should I and II be so close together? The reason is, of course, that the figures for Group I in Table XXII do not represent a real "sample" of the fish "population," which is being investigated, and the consideration of this point is of some importance since it points to a source of error which is inherent in all

fishery statistical investigations, that is, the material studied consists of samples, and these are collected by apparatus which does not, as a rule, give a sample really representative of the natural population which we wish to investigate. Fish samples, as well as plankton samples, are taken by means of nets which catch some things, but do not catch others, or which catch some things in much

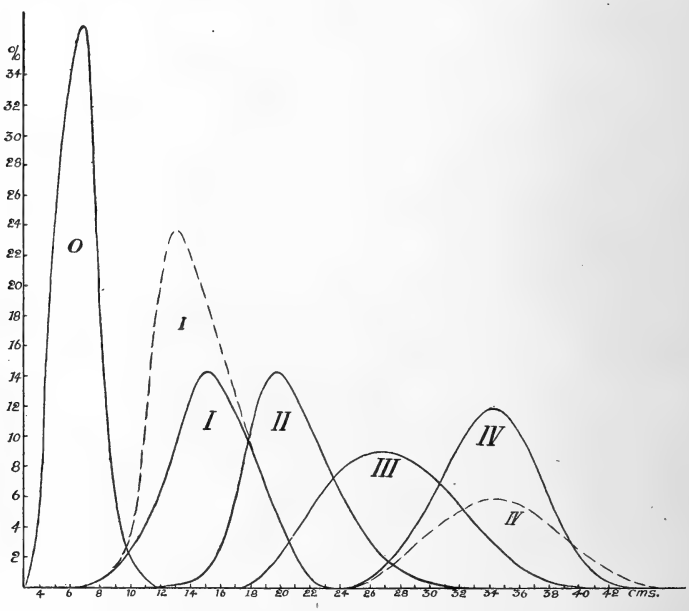


FIG. 4. Age-groups of Plaice in the Eastern waters of the Irish Sea. Figures on the vertical axis are percentages of all the fish of each group caught. Figures on the horizontal axis are the lengths of the fish. The smooth lines in the figure pass near the points actually plotted. The broken lines represent the probable shapes of the curves for Groups I and IV if very large series of measurements were obtainable.

greater proportions than they catch others. We assume, for instance, that the ratio between the numbers of copepods, peridinians and diatoms taken in a plankton net are just the ratios in which these organisms exist in the sea; or that the ratio between the numbers of plaice of one

and two years of age taken in the six-inch trawl net is also the ratio between those fishes living on the fishing grounds. Unless we had some means of investigating the "catching power" of plankton nets and fish-trawls, we should have to stick to this postulate; but we do know that a plankton net of No. 20 silk does not give us a real sample of copepods or fish eggs, while it may give us a real sample of the larger diatoms; and we also know that a trawl-net of 6-inch mesh gives us a real sample of plaice of Group II, but not a real sample of Group I or Group IV. The same source of error is inherent in each of the plankton and fish-nets: the copepods and fish eggs enter the plankton net, and are, to some extent, swirled out again, and the smaller diatoms pass through the meshes of the silk; while the larger plaice of Group IV enter the 6-inch trawl net, and may escape out from its mouth, while the small ones of Groups O and I escape through the meshes. It seems easy enough to remedy this defect in the collecting methods: we might use simultaneously plankton nets of different meshes, or fish-trawls of different mesh dimensions; and as a matter of fact, this has been attempted. Plankton nets of coarse and fine silk are employed, and fish-trawls of ½, 4, 6, and 7-inch meshes are employed, for the collection of pelagic organisms and of fishes. But again, we must consider whether or not we have employed just the right sorts of nets, and whether we have obtained just the right numbers of samples from each. Do, for instance, parallel hauls with plankton nets of (say) 10 and 20 silk, or parallel hauls with ½-inch and 6-inch trawl-nets sample the plankton and fish population? We are, I think, able to answer this question in regard to the fish samples, but I do not know of any easily-available means of answering it in the case of the plankton samples. And yet, until we can answer the questions indicated, and then

subject the results obtained to rigid statistical analysis, with due consideration of the errors involved, the crude results of experiments have questionable value.

The graph of Age-Group I in Fig. 4 has, therefore, been constructed from plaice examined in 1913. These fish were caught by means of both shrimp-trawl and fish trawl nets, that is, nets of ½-inch and 6-inch meshes, and the number caught in the smaller net was about double that taken in the larger mesh net. It is obvious that this combination of nets does take plaice of every length contained on the ground sampled, but it is doubtful whether the proportion of each (say) 5 cm. range of lengths caught is truly representative of the proportions of fish at those lengths actually living on the sea bottom. If the frequencies actually obtained be integrated, and the results then plotted, we obtain a curve which shows very clearly two modes, one at about 12·5 cms., and the other at about 18 cms. It is very unlikely that such a distribution is a natural one: if it were, we should have to conclude that we were not dealing with a homogeneous population, but with one consisting of two "races," that is, with one race of plaice which had a modal length of 12·5 cms. at the end of the second year of life, and another which had a modal length of 18 cms.—a condition which is very unlikely. If, however, we "smooth" these integrated frequencies, that is, draw a curve as evenly as possible near to all the points, but still a curve which will give only a single point of inflexion, we obtain a modal length for the group of about 15 cms., and this is the curve which is shown in Fig. 4.

There is little doubt that the series for Group O is a reliable one, and that the curve for this group given in Fig. 4 really represents the naturally occurring population. It shows that at the end of the yearly season of

growth there are practically no plaice below 4 cms. in length: this limit represents the minimum size to which plaice grow in their first year of life. Also there are practically no plaice, in the first year, of lengths greater than about 12 cms.; this limit represents the maximum size to which the fish grows in Lancashire waters during its first year. So, also, the curve for Group II appears to be a natural one, for plaice between about 12 and 30 cms. in length would be caught by a 6-inch trawl-net in very much the proportions in which they actually exist on the fishing grounds. It is also probable that the curve for Group III is a fairly accurate one, but that for Group IV does not seem right: it ought to have a greater dispersion, so that the frequency at the mode ought not to rise so high as is shown in the figure. The catches made do not, in fact, really represent the frequencies of this age-group in Lancashire waters, because plaice of over four years in age are relatively scarce on these fishing grounds, and the samples so far obtained are not really representative ones. The curve for Group IV ought to be flatter, just as that for Group I ought to be steeper. This modification is suggested by the curves drawn in broken lines, and it is hoped that further study of the age-groups will bear out the suggested alteration of the modal lengths so far actually observed.

We may, therefore, summarise the results of this section as follows:—

Modal Lengths of Plaice in Lancashire Waters:—

Plaice of Age-Group O (that is, over 0 and under 1 year of age) are, on the average, 7 cms. ($2\frac{3}{4}$ in.) long.

Plaice of Age-Group I (that is, over 1 and under 2 years of age) are, on the average, about 13 cms. ($5\frac{1}{4}$ in.) long.

Plaice of Age-Group II (that is, over 2 and under 3 years of age) are, on the average, about 19·5 cms. ($7\frac{3}{4}$ in.) long.

Plaice of Age-Group III (that is, over 3 and under 4 years of age) are, on the average, about 26·5 cms. ($10\frac{1}{2}$ in.) long.

Plaice of Age-Group IV (that is, over 4 and under 5 years of age) are, on the average, about 33 cms (13 in.) long.

Fish larger and older than these do, of course, frequently occur, but, for all practical purposes, the above groupings represent the plaice of economic importance present in the inshore waters of Lancashire, Cheshire and North Wales.

(5) Distribution of the Age-Groups on the Fishing Grounds.

One of the objects for which the ages of the fish samples were determined was that of ascertaining to what extent the various years of life were represented on the various grounds. The material available for the discussion of this question is given in the Tables published in former reports on the plaice measurements, but I think it hardly worth while grouping the figures with this object —in the meantime at least. It is doubtful whether the observations are numerous enough for this purpose, but a more serious objection is that the samples received may not have been representative ones. As a rule, only a part of the catch—from 50 to 100 fish—was sent to the laboratory for examination. The samples sent from the "James Fletcher" seem to me to represent fairly well the distribution of the whole catch made, but this has not been the case with other samples. To find whether the samples are, or are not reliable would mean plotting the distributions against each other—that of the whole catch,

and that of the sample,—and then endeavouring to "weight" the means of the several cm. groups accordingly. Until the data are more numerous, and until the samples are more regularly taken it does not seem worth while undertaking this work.

The material that we do possess does, of course, differ in the composition of the catches of fish made on the various grounds, and these differences are very much what one would suspect to exist. For instance, a rough estimate of the proportions of Age-Groups I to III in the catches made on the Nelson Buoy grounds during May to August, and on the Beaumaris-Red Wharf grounds during October to January gives the following figures:—

Nelson Buoy.		Beaumaris, Red Wharf Bays.
Age-Group I.	16%	11%
Age-Group II.	72%	75%
Age-Group III.	11%	13%

These show that the plaice population on the latter grounds is an older one—very slightly older—than on the former grounds. But no age-groups beyond the third are considered, for the numbers of the larger fish received are too small to utilise with confidence. It is, however, the case that the larger and older fish are far more numerous on the North Wales than on the Lancashire ground, but with respect to the younger groups the difference does not appear to be a great one. What we have is a native population which in both cases has approximately the same length distribution, but with, in the case of the winter fishery, a distinct population of older fish superadded by migration from other grounds.

(6) The Question of Size-Limits.

These plaice measurements provide, for the first time since the Committee began to make scientific investigations, satisfactory data for the discussion of possible size-limits. By interpolating on carefully drawn curves constructed from the integrated frequencies, the percentages of fish present on the grounds above or below any specified length can be found. Thus if we wish to consider what would be the effect of a size-limit of 20·5 cms.—just over 8 inches—we shall find that the following proportion of all the plaice caught by means of a 6-inch trawl mesh fall below this limit.

	Nelson Buoy grounds.	Horse Channel grounds.	Beaumaris and Red Wharf Bay grounds.	Luce Bay.
January	—	—	23%	—
February	—	—	—	—
March	—	—	—	—
April	—	54%	—	—
May	67%	54%	—	—
June	58%	69%	42%	—
July	50%	51%	37%	—
August	39%	28%	38%	—
September	45%	28%	36%	—
October	43%	28%	59%	22%
November	—	—	27%	
December	—	—	20%	

By similar means we can, of course, find the corresponding figures for any other proposed size-limits.

It will be seen also that the adoption of any such size limit would differentiate in favour of one class of fishermen and against others. A 20·5 cm. size-limit would obviously prevent about one-half of all the fish caught on the Nelson Buoy grounds from being landed. Presumably such legislation would have for its object the prevention of trawling on such a ground as this, the argument being that

the fishermen would refrain from fishing on such small plaice grounds if they were prevented from landing the bulk of the fish caught. Now, these grounds are largely exploited by second-class sailing trawlers. The imposition of a size-limit can only be justified by postulating that the fish that would otherwise be taken by unrestricted trawling will remain alive in the sea, migrate to other grounds and grow to a size at which their commercial value will become very considerably greater. This migration occurs, although we may not be prepared to say that all the fish, which the imposition of a size-limit would leave uncaught, will survive and grow at the normal rate: it is likely that "thinning-out" the plaice population of these grounds by trawling leads to the more rapid growth of the survivors. Suppose, however, that the migration and growth of the plaice left uncaught by the proposed restriction proceed as suggested in this report. Then we save the fish which would have been caught by the second class vessels to be caught by the smacks working offshore, and in the Beaumaris-Red Wharf area, in the winter months.

Following up the same argument we see that a size-limit of 20·5 cms. would prevent some 40 to 50 % of plaice living in the Red Wharf Bay area from being landed during the months of June to October, supposing that it were worth while to trawl on these grounds during this period. It would prevent the landing of some 20 % to 30 % of the plaice caught during the months of November to January, but this would probably not prevent trawling with nets of 6-inch mesh, for it would still be profitable for the smacks to work on these grounds even if they were obliged to return (dead or alive) to the sea all the plaice less than 20·5 cms. taken by them. It might then be urged that a size-limit of 20·5 cms. effective in preventing trawling on the Nelson Buoy grounds would be ineffective

in the case of the winter fishery, and a higher size-limit would be demanded. This would now differentiate against the smacks, and in favour of the steam trawlers who would (supposing that the argument is sound) fish for these plaice after they had migrated from out the Beaumaris-Red Wharf area into the deeper waters to the mouth of St. George's Channel.*

(7) The Length-Weight Coefficient *k*.

This has been determined in the case of all samples of plaice received at the laboratory. The fish were sorted and weighed, and then the average weights on the 1 cm. groups were calculated, and from these series the coefficient k in the expression $\int_{l_2}^{l_1} kl^3 dl$ was evaluated as described in previous reports.

By using tables of the fourth powers of the numbers 15·5 to 35·5 (the commonly occurring mean lengths), and of the logarithms of the powers of these numbers, the calculations of k were rapidly and accurately made. The results are given in Table XV (for the year 1913) and XXV (for the years 1909-1913).

It is doubtful whether (so far at least) these results have any useful or even theoretical application. If the series of samples examined during the years 1909-1913 had been more numerous, had, in fact, been really representative of the fisheries studied, then something might have been deduced from the tables of k-values. As it is the series are too incomplete to be of much use.

Anyhow the results are summarised in Table XXV, and I give here a graph of the mean values of k for the whole district investigated, and for all the years 1909-1913. The curve is drawn smoothly through a series of

*This question is further discussed in the introduction to the Report on the plaice-marking experiments in the present Report.

rather irregularly distributed points, but it seems certainly to have the general shape represented. It rises more quickly to a maximum about the end of July than it falls away from this maximum. Superposed on it is a curve of the variation of sea-temperature at the Liverpool North-West Light Vessel in 1912, and it will be seen that the variation in the value of the coefficient *k* is of the same nature, and very much the same extent as that of the variation in sea temperature: in other words immature plaice are in best condition when the sea temperature is higher than when it is lower than the mean—a result which was, of course, to be expected.

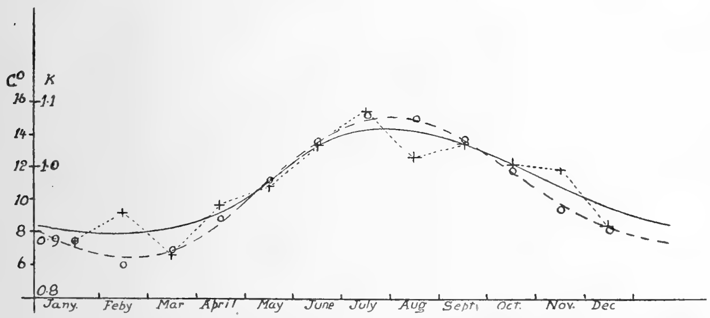


Fig. 5. Variation of the length-weight coefficient *k*, and of the Sea-temperature. The unbroken line represents the variation of *k*, the broken line that of Sea-temperature. O—points relate to temperature, +—points to *k*.

The correspondence is not so close as it might have been made if we had been able to obtain better series of samples. The samples taken at the end of the year are mainly those from the Red Wharf Bay area, and here the temperature of the sea is higher than it is at Liverpool North-West Light Vessel. Also comparatively few samples have been obtained during the early months of the year: had there been more we should have obtained lower values of *k*. That is to say, if we could "weight" *k*-values, or the temperature values, so that each series

were as representative of the general conditions as the other, we should get, I think, a very close correspondence.

So far as we have been able to study them the *k*-values do not seem to be very useful. But that is because of the fewness and irregularity and unrepresentative nature of the samples. There is little doubt that numerous and precise data, if we could obtain them, would be of service in explaining anomalous results with respect to migrations and length-distributions, and would, perhaps, prevent us from falling into error in interpreting such unusual results.

Table I.

	Duddon Bank, October, 1913.	King William Bank, March, 1913.	Between King William Bank and Selker Ship, February, 1913.
17·5	15	—	—
18·5	29	—	—
19·5	25	1	5
20·5	18	—	3
21·5	16	1	5
22·5	5	—	4
23·5	6	—	6
24·5	8	2	6
25·5	3	—	5
26·5	7	—	4
27·5	7	1	4
28·5	7	—	1
29·5	—	1	1
30·5	2	—	—
31·5	—	1	—
32·5	2	1	—
33·5	—	2	4
34·5	—	1	1
35·5	—	—	—
36·5	—	2	1
37·5	—	—	1
38·5	—	1	1
39·5	—	1	1
40·5	—	1	—
41·5	—	—	—
42·5	—	—	—
43·5	—	—	1
44·5	—	—	—
45·5	—	1	—
46·5	—	1	1
47·5	—	—	1
	150	18	56

Table II.—Blackpool to Liverpool Bar. 6 inch Mesh, 1913.

	May.	June.	July.	August.	September.
10·5	—	—	—	—	—
11·5	—	—	—	—	—
12·5	—	—	—	—	—
13·5	1	—	—	—	1
14·5	7	1	1	—	3
15·5	4	1	—	2	4
16·5	8	2	17	35	15
17·5	25	3	63	155	68
18·5	30	5	218	324	153
19·5	22	14	378	392	201
20·5	29	13	237	467	281
21·5	12	13	101	280	245
22·5	18	4	47	158	203
23·5	11	5	26	81	109
24·5	10	2	12	41	74
25·5	3	4	10	23	43
26·5	5	1	7	22	28
27·5	4	3	3	15	12
28·5	1	—	2	13	12
29·5	—	1	2	4	10
30·5	—	—	—	4	7
31·5	—	1	—	3	2
32·5	—	—	1	2	4
33·5	1	—	—	1	2
34·5	—	—	—	3	3
35·5	—	1	—	—	—
36·5	—	—	—	—	1
37·5	—	—	—	—	1
38·5	—	—	—	—	—
39·5	—	—	—	—	—
40·5	—	—	—	—	—
41·5	—	—	—	1	—
	191	74	1125	2026	1482

Table III.—Mersey Estuary. 6 inch mesh. 1913.

	Mar.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
10·5	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—	—
12·5	8	—	—	1	—	—	—	—	—
13·5	7	—	—	—	—	—	—	—	—
14·5	7	2	—	3	—	—	—	—	—
15·5	24	9	1	6	1	—	3	—	—
16·5	41	8	6	30	—	2	17	4	—
17·5	49	26	53	151	25	8	81	10	—
18·5	51	22	95	438	76	30	277	31	1
19·5	34	46	67	571	171	81	441	32	—
20·5	33	33	37	507	241	109	424	73	2
21·5	40	20	13	386	177	87	427	59	—
22·5	17	16	3	233	110	67	274	56	—
23·5	7	2	1	93	61	26	190	37	—
24·5	3	—	3	43	36	27	109	18	1
25·5	1	3	—	20	16	16	52	15	—
26·5	—	—	—	6	6	6	29	11	—
27·5	—	—	—	8	2	6	21	7	1
28·5	—	1	—	2	1	3	7	2	—
29·5	—	—	—	1	—	1	7	4	—
30·5	—	—	—	1	3	—	2	3	—
31·5	—	—	—	2	1	2	1	2	—
32·5	—	—	—	1	—	1	2	1	—
33·5	—	—	—	—	—	1	—	1	1
34·5	—	—	—	2	—	1	1	3	—
35·5	—	1	—	1	—	1	—	—	—
36·5	—	—	—	—	—	—	—	—	1
37·5	—	—	—	—	2	1	—	—	1
38·5	—	—	—	—	—	—	—	—	1
39·5	—	1	—	1	—	1	—	—	—
40·5	—	—	—	2	—	—	1	1	—
41·5	—	—	—	—	1	—	1	2	—
42·5	—	—	—	—	1	—	—	—	1
43·5	—	—	—	—	—	—	—	—	—
44·5	—	—	—	—	—	—	1	—	—
45·5	—	—	—	—	1	—	1	—	—
	322	190	279	2509	932	477	2369	372	10

Table IV. Mersey Estuary. ½ inch mesh. 1913.

	Jan.	Feb.	April.	May.	June.	July.	Aug.	Oct.	Nov.	Dec.
4·5	—	—	—	—	1	—	—	1	—	—
5·5	1	5	—	—	—	1	—	3	3	6
6·5	7	8	4	8	1	—	—	1	7	18
7·5	14	11	4	8	10	—	1	1	8	41
8·5	27	9	12	4	46	3	1	1	12	44
9·5	33	7	22	20	108	6	2	3	10	19
10·5	63	15	52	28	96	9	10	8	7	13
11·5	147	21	160	60	92	17	10	20	3	10
12·5	112	5	341	84	149	21	5	20	—	6
13·5	84	5	392	100	183	40	11	6	2	6
14·5	49	3	379	212	191	23	10	14	1	—
15·5	37	1	328	124	159	27	30	5	1	2
16·5	8	—	189	148	157	9	19	6	—	—
17·5	11	—	97	93	78	10	3	5	—	—
18·5	1	—	33	72	53	7	15	3	—	—
19·5	3	—	12	32	39	9	10	4	—	—
20·5	—	—	13	6	23	2	6	3	—	—
21·5	1	—	—	2	3	2	4	2	—	—
22·5	3	—	5	2	1	2	—	—	—	—
23·5	—	—	—	2	2	—	3	—	—	—
24·5	1	—	4	3	—	—	1	—	—	—
25·5	—	—	—	—	1	—	—	—	—	—
	602	90	2047	1008	1393	188	141	106	54	165

Table V.

Beaumaris and Red Wharf Bays. 6 inch mesh. 1913

	April.	May.	June.	July.	Aug.	Sept.	Oct.	Dec.
10·5	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—
12·5	—	1	—	—	—	—	—	—
13·5	—	—	—	—	—	—	—	—
14·5	1	—	—	—	—	—	—	—
15·5	1	1	1	—	1	—	—	—
16·5	1	2	3	—	1	2	—	1
17·5	2	—	14	4	9	14	2	—
18·5	13	7	48	21	49	45	5	2
19·5	6	6	82	66	84	70	7	10
20·5	12	5	76	82	109	61	26	31
21·5	8	2	47	56	105	51	38	29
22·5	5	5	24	35	63	57	26	50
23·5	4	—	14	11	51	38	18	34
24·5	3	1	14	13	35	34	19	48
25·5	1	—	6	7	20	11	10	19
26·5	2	3	2	3	18	10	12	20
27·5	3	—	2	2	13	6	6	12
28·5	2	1	—	2	10	3	8	4
29·5	—	1	2	—	8	10	2	—
30·5	2	—	1	—	7	2	5	—
31·5	1	—	2	1	7	4	4	2
32·5	1	1	—	1	3	2	1	1
33·5	—	1	1	—	3	—	1	—
34·5	—	—	—	—	2	—	—	—
35·5	—	1	—	—	—	—	—	—
36·5	—	2	—	—	1	—	—	—
37·5	1	—	—	1	2	—	—	—
38·5	—	2	—	—	1	—	—	—
39·5	1	2	—	—	—	—	—	—
40·5	—	—	2	—	—	—	—	—
41·5	—	1	—	—	—	—	—	—
42·5	—	1	—	—	—	—	—	—
43·5	—	—	—	—	—	—	—	—
44·5	—	1	—	—	—	—	—	—
45·5	2	—	—	—	—	—	—	—
46·5	1	—	—	—	—	—	—	—
47·5	—	1	—	—	—	—	—	—
48·5	1	—	—	—	—	—	—	—
54	—	1	—	—	—	—	—	—
	74	49	341	305	602	420	190	263

Table VI. Menai Straits. 6 inch mesh. 1913.

	Jan.	Mar.	April.	June.	Sept.	Oct.	Nov.	Dec.
10·5	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—
12·5	—	—	—	—	—	—	21	—
13·5	—	—	—	—	—	25	35	—
14·5	—	—	—	—	—	1	10	—
15·5	21	—	1	—	—	—	29	—
16·5	35	2	5	2	—	7	18	1
17·5	25	8	6	9	2	17	42	4
18·5	36	13	3	18	4	52	49	9
19·5	38	11	2	10	11	60	58	3
20·5	59	17	3	9	12	43	37	9
21·5	26	5	3	6	12	39	39	4
22·5	22	5	—	3	5	35	16	10
23·5	27	4	3	2	4	23	24	7
24·5	17	2	—	—	1	13	18	5
25·5	9	3	—	—	3	8	6	2
26·5	5	2	—	1	1	4	3	2
27·5	2	3	—	—	2	9	2	—
28·5	2	1	2	—	—	1	1	—
29·5	2	2	3	—	2	5	1	1
30·5	—	3	—	—	1	1	—	—
31·5	2	—	—	—	—	1	—	1
32·5	2	—	5	—	1	4	—	—
33·5	—	—	5	—	1	—	—	—
34·5	—	—	2	—	—	4	1	—
35·5	—	—	1	—	—	1	—	—
36·5	—	—	2	—	—	2	—	—
37·5	—	—	—	—	—	2	1	—
38·5	—	—	2	—	—	—	2	—
39·5	—	—	1	—	—	1	2	—
40·5	—	—	—	—	—	—	—	—
41·5	—	—	—	—	1	—	—	—
42·5	—	—	—	—	—	—	—	—
43·5	—	—	—	—	—	—	—	—
44·5	—	—	—	—	—	1	—	—
45·5	—	—	—	—	—	1	—	—
48·5	—	—	—	—	1	—	—	—
53·5	—	1	—	—	—	—	—	—
	330	82	49	60	64	360	415	58

Table VII. Carnarvon Bay, 6 inch mesh. 1913.

	February.	April.	May.	June.	July.	August.
16·5	1	—	1	—	1	—
17·5	—	—	11	4	2	5
18·5	1	—	49	17	4	21
19·5	1	—	64	35	13	27
20·5	1	—	64	49	23	63
21·5	—	—	37	34	25	43
22·5	—	—	39	31	48	41
23·5	1	—	26	16	42	36
24·5	—	—	19	11	19	34
25·5	—	—	11	7	17	10
26·5	—	1	14	7	16	10
27·5	—	—	11	11	13	3
28·5	—	—	10	6	7	1
29·5	—	1	10	2	—	1
30·5	—	—	8	2	1	—
31·5	—	1	6	1	—	—
32·5	—	—	5	2	3	—
33·5	—	1	3	—	—	—
34·5	—	—	6	1	1	—
35·5	—	—	5	3	—	—
36·5	—	—	3	—	—	—
37·5	—	—	4	1	—	—
38·5	—	—	—	—	—	—
39·5	—	—	1	—	—	—
40·5	—	—	2	—	—	—
41·5	—	1	—	—	—	—
42·5	—	—	1	—	—	—
43·5	—	—	—	—	—	—
44·5	—	—	1	—	—	—
45·5	—	—	—	—	—	—
46·5	—	—	—	—	—	—
47·5	—	—	—	—	—	—
48·5	—	—	1	—	—	—
	5	5	412	240	235	295

Table VIII. Cardigan Bay, 6-inch mesh. 1913.

	January.	February.	May.	June.
12·5	6	—	—	—
14·5	7	—	—	—
15·5	9	—	—	—
16·5	—	—	—	—
17·5	8	—	19	5
18·5	6	—	78	2
19·5	4	—	76	5
20·5	4	1	77	18
21·5	5	2	61	15
22·5	—	—	72	21
23·5	9	3	60	17
24·5	3	—	66	9
25·5	1	—	62	8
26·5	—	—	56	7
27·5	—	—	41	4
28·5	—	—	36	8
29·5	1	—	16	1
30·5	3	—	14	2
31·5	—	—	7	2
32·5	—	—	11	1
33·5	—	—	2	1
34·5	—	—	1	1
35·5	—	—	—	1
36·5	—	—	—	1
37·5	—	—	—	1
38·5	—	—	—	—
39·5	—	—	—	—
40·5	—	—	—	—
41·5	—	—	—	—
42·5	—	—	—	—
43·5	—	—	—	1
44·5	—	—	—	—
45·5	—	—	—	—
46·5	—	—	—	—
47·5	—	—	—	—
48·5	—	—	—	1
	66	6	755	132

Table IX. Morecambe Bay. 1913.

	April.						May.							July.						October.					
	♂			♀			♂				♀			♂			♀			♂			♀		
	1	2	3	1	2	3	1	2	3	4	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
10·5																									
11·5																									
12·5							1																		
13·5																									
14·5														1			2								
15·5							4	4			3	3		1	1		1			2			1		
16·5							6	5			1	7		4	1		3	3			1		6	1	
17·5	4			8				9	1			10		5	2		3	2					7		
18·5	5			11				7				8			5		1	1			5		15	2	
19·5	1			2	6							3			4			1		2	6		2	5	
20·5	1	2		3	4			1				2						1	1	2	6		1	6	
21·5	1	1			3			1				1			1					2	2				
22·5	1	2			1					1											3			2	
23·5		2			1								1								2	1		4	
24·5		1														1						1		1	
25·5		1		1	1				1															3	1
26·5		1				1																1			
27·5					1																				1
28·5		2				1													1						
29·5																									
30·5			1																						
31·5																									
32·5																									
33·5																									
34·5																									
35·5																									
36·5																									
37·5																									
38·5																									
39·5																									
40·5																									

Table X. Near Nelson Buoy. 1913.

	May.				June.						July.						August.					September.						
	♂		♀		♂		♀				♂			♀			♂			♀		♂			♀			
	1	2	1	2	2	3	1	2	3	4	1	2	3	1	2	3	1	2	3	2	3	1	2	3	1	2	3	4
10·5																												
11·5																												
12·5																												
13·5	1						1																					
14·5																												
15·5	2						1																		1			
16·5	2		1				1	2						1	1			1		1		1	1			1		
17·5	5	1	4					4				1			3		1	4		1			2					
18·5	3	1	5	1	3			3				21			9	1		16		12	1		3			4		
19·5	1	2	3		5	1	1	5				18	1		18			14		15			4			6		
20·5	2	2		2	3	2		7	3			12			8			14		9	1		7			10		
21·5		3		2	1	1		4	3	1		2			8			5	2	7	2		10			10		
22·5		4		1		3			1			1			3	1			1	2			8			6		
23·5		2		1	1	1			4						2	1			2		2		4	2		3		
24·5						1			2				2			1										2	3	
25·5		1							2				1			2			1					2		2	2	
26·5		1				1			1										1		1			1				
27·5				1		1			1																		1	1
28·5																1								1			1	
29·5						1																						
30·5									1																			
31·5																												
32·5																												
33·5																												
34·5									1																			
35·5																												
36·5																											1	
37·5																												
38·5																												
39·5																												
40·5																												

Table XI. Mersey Estuary. 1913.

	Jan.*		March.								April.								May.						June.				
	♂ ♀		♂ ♀		♂			♀			♂ ♀		♂			♀			♂			♀			♂ ♀	♂		♀	
	0	1	1	2	1	2	3	1	2	3	1	2	1	2	3	1	2	3	1	2	3	1	2	3	1	1	2	1	2
4·5	16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5·5	103	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6·5	148	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7·5	88	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...
8·5	39	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...	9	...	...	...	...
9·5	6	2	...	...	...	...	...	...	...	...	6	...	...	...	...	...	...	...	...	...	...	...	...	...	13	...	...	...	...
10·5	3	2	...	...	...	...	...	...	...	...	11	...	...	...	...	...	...	...	...	...	...	...	...	...	12	...	...	...	...
11·5	2	4	1	...	...	...	...	...	...	...	25	...	...	...	...	...	...	...	...	...	...	...	...	...	8	...	...	...	...
12·5	...	8	8	...	...	...	...	...	...	...	59	...	...	...	...	...	...	...	...	...	...	...	...	...	7	...	...	...	...
13·5	...	...	4	...	...	...	...	...	...	...	76	...	...	...	...	...	...	...	...	...	...	...	...	...	7	...	...	...	...
14·5	...	1	7	...	...	...	...	...	...	...	78	3	...	...	...	...	...	...	1	...	...	1	...	...	11	...	...	...	...
15·5	...	1	4	1	2	...	...	1	...	...	46	8	...	...	...	...	...	...	3	...	...	2	...	...	...	2	3	6	2
16·5	...	...	...	2	3	2	...	4	...	...	...	...	27	5	...	3	5	...	4	...	...	6	...	...	...	13	2	10	2
17·5	...	...	...	...	1	...	...	4	2	...	...	...	17	4	...	7	9	...	3	...	...	8	1	...	...	3	3	7	5
18·5	...	...	...	2	3	3	...	2	4	...	...	...	2	3	...	4	2	...	5	1	...	5	...	...	...	1	2	...	8
19·5	...	...	...	1	...	7	...	...	9	...	...	...	...	4	...	1	7	...	...	5	...	4	7	...	...	...	2	...	8
20·5	...	...	...	...	...	6	1	...	7	...	...	...	1	11	...	...	5	...	1	4	...	2	13	...	...	...	...	...	1
21·5	...	...	...	...	...	5	1	...	12	3	...	...	...	9	...	...	8	...	...	4	1	...	11	...	...	...	...	...	1
22·5	...	...	...	...	...	5	1	...	5	2	...	...	...	2	1	...	5	2	...	4	...	...	5	1	...	...	...	...	...
23·5	...	...	...	...	...	1	...	...	1	...	...	...	...	...	...	...	...	2	...	...	1	...	...	...	...	...	...	...	1
24·5	...	...	...	...	...	...	...	...	1	...	...	...	...	...	1	...	2	2	...	...	...	...	...	...	...	...	...	...	...
25·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	2	...	...	...	...	...	...
26·5	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...
27·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

* 1914. The symbol ♂ ♀ means that the sexes have not been distinguished.

Table XI—*Continued.*

	July.					August.					October.								November.							December.		
	♂		♀			♂		♀			♂ ♀			♂		♀			♂ ♀			♂		♀		♂ ♀		
	2	3	1	2	3	1	2	1	2	3	0	1	2	2	3	1	2	3	0	1	2	1	2	1	2	0	1	2
4·5											2								2									
5·5											7								65							3		
6·5											3	1							98	3						14	3	
7·5											3	2							65	5						29	8	
8·5												2							7	1						24	1	
9·5												4							2							7	4	
10·5												11	2						1	6						6	6	
11·5												33	2							20						2	7	
12·5												45	4							19	4						2	
13·5												31	3							25	2						2	1
14·5												16	7							24	3						2	
15·5												6	5			3						9	3	10	2		1	3
16·5												3	2			3	5					11	9	10	4			
17·5	1			2		1	3	1	1			3	1	3		2	2					5	4	1	4			
18·5	1		1	3			5						3	5		2	2					1	5		7			
19·5	7			9			7		5				4	8		1	12						1					
20·5	6			7			4		6				5	12	1		11								1			
21·5	4	1		9			5		7					9			9	2										
22·5	6			6			4		8				1	10			7											
23·5	2				2		8							2			2											
24·5					3		3		1	1					1		2											
25·5									1	1				2	1													
26·5																												

The Symbol ♂ ♀ means that the sexes have not been distinguished.

Table XII. Beaumaris and Red Wharf Bays. 1913.

	May.							June.								July.							
Sex ...	♂				♀			♂				♀				♂				♀			
Group ...	1	2	3	4	1	2	3	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
10·5																							
11·5																							
12·5																							
13·5																							
14·5																							
15·5								2															
16·5	3				3	1		1				2									2		
17·5	4	4			9	4		2	1			2											
18·5	19	9			22	7		9	3			4	5				2				2		
19·5	9	11			9	5		6	3			9	6				8				17		
20·5	1	14				19		1	4			8	7				7				9	3	
21·5		7	1			6	1	1	2			3	3				7	1			10	2	
22·5		10				3			1				2	1			1	1			4	2	
23·5		8				4	3						1	1				2			3	2	
24·5		3	1			6	2		2				2	1			1					4	
25·5		3				1	2										3						
26·5							2						1	1				1				1	
27·5			1	1										1									
28·5			2				2											1				1	
29·5							1							1									
30·5							1																
31·5							1							2					1				1
32·5			1				1								1								
33·5																							
34·5																							
35·5							1																
36·5																						1	
37·5																							
38·5																							
39·5											1												
47·5																							

	Aug.				Sept.						Oct.							Nov.								Dec.						
Sex ...	♂		♀		♂			♀			♂				♀			♂					♀			♂			♀			
Group ...	2	3	2	3	1	2	3	1	2	3	1	2	3	4	1	2	3	1	2	3	4	5	1	2	3	1	2	3	1	2	3	5
10·5																																
11·5																																
12·5																																
13·5											1																					
14·5																																
15·5															1								1									
16·5											1												2	1								
17·5			2			2					2	1			2	2			1				2	1		1			1			
18·5	7					7			5		1	8			3	2			3				1	2		1	2		2	1		
19·5	14		10		1	9		1	5			7			1	5			2				1	5		1	11		1	10		
20·5	16		6	1		7			11			8				6		1	5					5			21			17		
21·5	8	1	13	1		4			5			2	1			3			5					10			16			19		
22·5	7	1	5	1		5	1		12			6				4			5					4			20	2		18		
23·5	3		5			4	2		5			5				5			4	1				5			8			18		
24·5	1	1	1	5		2	1		4	1		5				4			6					7			5	1		10	1	
25·5		1				1	1					2				2			3					2			1			2		
26·5		3		1								1				1	2		3	1				2						1		
27·5				1		1						1													1							
28·5		1																	2					1	1							
29·5		1					1			1			1																		3	
30·5													1												1							
31·5							1																									
32·5																									1							
33·5													2															1				
34·5																											1					
35·5																																
36·5																					1	1										
37·5														1																		
38·5																																
39·5																																
47·5																																1

Table XIII. Menai Straits. 1913.

	Mar.				Oct.				Nov.							Dec.					
Sex	♂			♀	♂		♀		♂			♀				♂			♀		
Group	2	3	4	2	1	2	1	2	1	2	3	1	2	3	4	1	2	3	1	2	3
10·5																					
11·5																					
12·5																					
13·5																					
14·5																					
15·5									1												
16·5					1		1					1							1		
17·5					3		2	2	7			11	1			1	2				
18·5				1	2	9	1	5	6	2		7	11			2	3			3	
19·5	2				3	5	2	6	2	15		3	12			1			2	1	
20·5				1		7	1	4		7			7			1	2			3	
21·5						4		9		3	1		3			1	4			1	
22·5				1	1	5	1	4		2							6			2	
23·5				1		4		6		1			1				4			3	1
24·5								1									2			4	
25·5		1				1							1				2			1	
26·5														1			1			1	
27·5		2												1							
28·5		1																			
29·5		1																		1	
30·5																					
31·5			1												1			1			
32·5																					
33·5																					
34·5																					
35·5																					
36·6																					
37·5																					
38·5																					
39·5																					
40·5																					
41·5																					
42·5			(9)																		
43·5																					
53·5			1																		

Table XIV. Carnarvon Bay. 1913.

	April.			May.								June.							July.				Aug.				Oct.			
Sex	♂		♀	♂				♀				♂				♀			♂		♀		♂		♀		♂		♀	
Group	3	5	2	1	2	3	4	2	3	4	5	1	2	3	4	1	2	3	2	3	2	3	1	2	1	2	2	3	1	2
10·5																														
11·5																														
12·5																														
13·5																														
14·5																														
15·5																														
16·5					1							1	1								1									
17·5					5			2				1	9			3	4				1								2	
18·5					9	1		10	1				7			2	13		6		1		1		1		2			1
19·5					10	1		5					8			1	5		7		2						7			2
20·5					6	4		2				1	8			1	6		5		3			2			4			3
21·5					1	3			3				3	1			7		5		6	1		1		1	2			4
22·5					1	4			4				1				4	1	8	1	9			1		2	1			1
23·5						1			2					2			1		2	2	3	1								
24·5						2		1	2				1						1	1		1		1			1	1		
25·5									1					1						1		2				1	1			1
26·5			1						1						1		1			1		1								1
27·5						1				1							1					1						1		
28·5																														
29·5	2					1				2																	1	1		
30·5										1																				
31·5							1																							
32·5							1																							
33·5	1																													
34·5							1			1																				
35·5																												1		
36·5																														
37·5										1																				
38·5																														
39·5																														
40·5																														
41·5		1																												
42·5																														
43·5											1																			
53·5																														

Table XV. Values of the Length-Weight Coefficient *k*. 1913.

	Morecambe Bay.	Near Nelson Buoy.	Mersey Estuary.	Beaumaris and Red Wharf Bays.	Menai Straits.	Carnarvon Bay.
January ...	—	—	—	—	—	—
February	—	—	—	—	—	—
March	—	—	0·785	—	—	—
April	0·948	—	0·832	—	—	—
May	0·948	0·819	0·949	0·950	—	0·898
June	1·029	0·909	0·866	0·926	—	0·904
July	—	1·010	1·019	0·985	—	1·035
August ...	—	0·997	0·999	0·835	—	—
September	—	0·981	—	0·937	—	—
October ...	1·048	—	0·959	0·964	0·955	—
November	—	—	0·848	0·966	0·985	—
December	—	—	—	0·916	0·911	—

Tables XVI—XXI.—Summaries of the Length-frequencies of Plaice taken on the various Fishing Grounds during the period 1908-1913.

Table XVI. Luce Bay, 1908-1912.

Length.	No.	%	Length.	No.	%
10·5	2	0·02	37·5	173	2·23
11·5	6	0·08	38·5	155	2·00
12·5	7	0·09	39·5	119	1·54
13·5	9	0·12	40·5	91	1·17
14·5	22	0·28	41·5	58	0·75
15·5	79	1·01	42·5	66	0·85
16·5	271	3·48	43·5	42	0·54
17·5	372	4·80	44·5	51	0·66
18·5	412	5·32	45·5	18	0·23
19·5	523	6·75	46·5	27	0·35
20·5	538	6·95	47·5	17	0·22
21·5	454	5·86	48·5	13	0·17
22·5	412	5·32	49·5	12	0·15
23·5	380	4·91	50·5	5	0·06
24·5	306	3·95	51·5	6	0·08
25·5	290	3·74	52·5	3	0·04
26·5	292	3·77	53·5	6	0·08
27·5	257	3·32	54·5	2	0·02
28·5	231	2·98	55·5	—	—
29·5	259	3·34	56·5	2	0·02
30·5	239	3·08	57·5	1	0·01
31·5	218	2·81	58·5	3	0·04
32·5	276	3·56	59·5	—	—
33·5	299	3·86	60·5	—	—
34·5	264	3·41	61·5	—	—
35·5	251	3·24	62·5	2	0·02
36·5	207	2·67			
			Totals ...	7,748	99·95

Table XVII. Blackpool to Liverpool Bar, 6-inch mesh. 1908-1913.

	May.		June.		July.		August.		September.		October.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	1	0·01	1	0·02	—	—
12·5	1	0·05	—	—	2	0·04	6	0·09	1	0.02	1	0.04
13·5	11	0·59	1	0·05	1	0·02	25	0·38	9	0·18	10	0·40
14·5	35	1·87	12	0·64	8	0·18	57	0·69	34	0·71	19	0·77
15·5	121	6·53	39	2·07	30	0·66	131	2·02	111	2·27	75	3·03
16·5	277	14·94	106	5·62	129	2·85	267	4·11	269	5·50	201	8·12
17·5	273	14·72	205	10·86	320	7·08	473	7·28	459	9·39	231	9·34
18·5	247	13·32	304	16·12	601	13·29	740	11·40	517	10·57	250	10·10
19·5	195	10·52	263	13·94	838	18·54	794	12·23	542	11·09	196	7·91
20·5	150	8·09	231	12·25	676	14·96	839	12·93	557	11·40	167	6·75
21·5	105	5·66	228	12·07	495	10·95	681	10·49	506	10·35	152	6·29
22·5	82	4·42	183	9·69	433	9·58	571	8·79	449	9·18	160	6·47
23·5	69	3·72	124	6·57	320	7·08	444	6·84	339	6·93	164	6·63
24·5	61	3·29	67	3·55	254	5·62	338	5·21	311	6·36	177	7·16
25·5	54	2·91	45	2·38	159	3·52	262	4·04	245	5·01	156	6·30
26·5	53	2·86	24	1·27	83	1·84	231	3·56	176	3·60	140	5·66
27·5	45	2·43	20	1·06	63	1·39	182	2·80	128	2·62	122	4·93
28·5	31	1·71	9	0·48	25	0·55	146	2·25	88	1·80	97	3·92
29·5	13	0·70	14	0·74	22	0·48	86	1·32	54	1·10	61	2·46
30·5	15	0·81	5	0·26	6	0·13	63	0·97	34	0·69	37	1·49
31·5	7	0·38	3	0·16	14	0·31	36	0·55	18	0·37	22	0·89
32·5	3	0·16	2	0·11	15	0·33	34	0·52	18	0·37	12	0·48
33·5	3	0·16	—	—	5	0·11	28	0·43	4	0·08	7	0·28
34·5	2	0 11	—	—	6	0 13	21	0·32	6	0·12	5	0·20
35·5	—	—	1	0·05	5	0·11	12	0·18	5	0·10	4	0·16
36·5	—	—	—	—	1	0·02	11	0·16	6	0·12	2	0·08
37·5	1	0·05	—	—	3	0·07	3	0·04	1	0·02	2	0·08
38·5	—	—	—	—	2	0·04	7	0·11	1	0·02	1	0·04
39·5	—	—	—	—	—	—	1	0·01	—	—	—	—
40·5	—	—	—	—	2	0·04	1	0·01	—	—	2	0·08
41·5	—	—	—	—	—	—	1	0 01	—	—	—	—
42·5	—	—	—	—	—	—	—	—	—	—	—	—
43·5	—	—	—	—	—	—	—	—	—	—	—	—
44·5	—	—	—	—	1	0·02	—	—	—	—	—	—
45·5	—	—	—	—	—	—	—	—	—	—	1	0·04
46·5	—	—	—	—	—	—	—	—	1	0·02	—	—
Totals	1,854	100·00	1,886	99·94	4,519	99·94	6,492	99·75	4,890	100·01	2,474	100·10

Table XVIII. Horse Channel, Mersey Estuary, 6-inch mesh. 1908-1913.

	April.		May.		June.		July.		August.		September.		October.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
11·5	—	—	3	0·06	—	—	—	—	—	—	—	—	—	—
12·5	—	—	8	0·17	—	—	2	0·04	2	0·03	—	—	—	—
13·5	8	0·28	10	0·21	8	0·20	5	0·11	17	0·25	2	0·10	—	—
14·5	8	0·28	39	0·83	42	1·07	39	0·82	56	0·83	6	0·32	—	—
15·5	29	1·06	112	2·38	144	3·66	95	2·01	96	1·42	8	0·42	6	0·37
16·5	123	4·36	256	5·44	476	12·10	228	4·82	159	2·35	40	2·11	31	1·89
17·5	262	9·29	499	10·61	661	16·81	409	8·66	291	4·29	117	6·16	85	5·20
18·5	467	16·57	756	16·07	775	19·70	738	15·63	510	7·52	143	7·53	154	9·42
19·5	547	19·40	864	18·37	601	15·28	897	19·00	768	11·32	183	9·64	235	14·38
20·5	441	15·64	682	14·50	518	13·17	803	17·00	870	12·83	253	13·32	158	9·67
21·5	297	10·54	541	11·50	283	7·20	624	13·21	846	12·48	240	12·64	228	13·98
22·5	243	8·62	407	8·65	196	4·98	412	8·72	717	10·58	201	10·59	149	9·12
23·5	153	5·43	242	5·14	109	2·77	213	4·51	611	9·01	137	7·21	127	7·77
24·5	119	4·22	131	2·79	59	1·50	114	2·41	562	8·29	148	7·79	106	6·49
25·5	52	1·84	71	1·51	24	0·61	53	1·12	366	5·40	114	5·60	82	5·01
26·5	28	0·99	34	0·72	14	0·35	28	0·59	351	5·18	96	5·06	70	4·28
27·5	21	0·75	18	0·38	6	0·15	17	0·45	222	3·27	69	3·63	61	3·73
28·5	6	0·21	14	0·29	3	0·07	12	0·25	158	2·33	54	2·84	50	3·06
29·5	6	0·21	3	0·06	6	0·15	4	0·08	73	1·08	40	2·11	33	2·02
30·5	4	0·14	5	0·11	2	0·05	3	0·06	48	0·71	19	1·00	18	1·10
31·5	—	—	5	0·11	3	0·07	4	0·08	20	0·47	14	0·74	13	0·79
32·5	1	0·07	2	0·04	1	0·02	5	0·11	13	0·19	2	0·10	12	0·73
33·5	2	0·14	—	—	1	0·02	2	0·04	4	0·05	4	0·20	6	0·37
34·5	—	—	—	—	1	0·02	3	0·06	4	0·05	4	0·20	3	0·18
35·5	—	—	1	0·02	—	—	2	0·04	6	0·07	2	0·10	3	0·18
36·5	1	0·07	—	—	—	—	3	0·06	1	0·01	—	—	1	0·06
37·5	1	0·07	—	—	—	—	1	0·02	—	—	—	—	1	0·06
38·5	—	—	—	—	—	—	1	0·02	—	—	2	0·10	—	—
39·5	—	—	—	—	—	—	3	0·06	1	0·01	—	—	1	0·06
40·5	—	—	—	—	—	—	3	0·06	—	—	—	—	1	0·06
41·5	—	—	—	—	1	0·02	—	—	—	—	—	—	—	—
42·5	—	—	—	—	—	—	—	—	3	0·03	—	—	—	—
44·5	—	—	—	—	—	—	—	—	1	0·01	—	—	—	—
46·5	—	—	—	—	—	—	—	—	1	0·01	—	—	—	—
Totals	2,819	100·18	4,703	99·96	3,934	99·97	4,723	100·04	6,777	100·07	1,898	99·51	1,634	99·98

Table XIX. Mersey Estuary, ½-inch mesh. 1908-1913.

	January.		February.		March.		April.		May.		June.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
3·5	—	—	—	—	—	—	—	—	—	—	—	—
4·5	406	2·97	52	1·27	40	0·54	38	0·76	—	—	1	0·07
5·5	2,586	19·38	558	13·72	216	2·91	496	9·96	—	—	—	—
6·5	2,903	21·76	846	20·80	551	7·43	594	11·93	14	0·34	1	0·07
7·5	3,018	22·62	787	19·35	1,422	19·19	514	10·32	20	1·68	13	0·92
8·5	2,054	15·39	788	19·36	1,754	23·67	207	4·16	27	2·27	51	3·62
9·5	896	6·72	249	6·12	875	11·80	150	3·01	54	4·54	111	7·87
10·5	435	3·26	158	3·08	337	4·55	177	3·56	53	4·46	98	6·94
11·5	415	3·11	102	2·51	437	5·89	242	4·86	76	6·39	93	6·59
12·5	214	1·60	100	2·46	387	5·22	428	8·60	98	8·24	150	10·63
13·5	173	1·30	69	1·35	293	3·95	449	9·02	106	8·91	185	13·11
14·5	96	0·72	97	2·38	225	3·04	482	9·68	217	18·25	191	13·54
15·5	75	0·56	99	2·43	256	3·45	420	8·43	132	11·10	159	11·27
16·5	27	0·20	59	1·45	211	2·85	303	6·08	158	13·28	158	11·20
17·5	25	0·19	35	0·86	135	1·82	208	4·18	102	8·58	78	5·53
18·5	7	0·05	21	0·52	110	1·48	106	2·13	78	6·52	53	3·76
19·5	6	0·04	15	0·39	73	0·98	72	1·44	35	2·94	39	2·76
20·5	1	0·00	15	0·39	47	0·63	44	0·88	8	0·67	23	1·67
21·5	2	0·01	9	0·22	17	0·23	17	0·34	3	0·25	3	0·21
22·5	3	0·02	5	0·12	12	0·16	20	0·40	2	0·17	1	0·07
23·5	—	—	2	0·05	5	0·07	4	0·08	2	0·17	2	0·14
24·5	1	0·00	1	0·02	12	0·16	5	0·10	4	0·33	—	—
25·5	—	—	1	0·02	4	0·06	2	0·04	—	—	1	0·07
Totals	13,343	99·90	4,068	99·87	7,419	100·08	4,978	99·96	1,189	99·09	1,411	100·04

Table XX. Mersey Estuary, ½-inch mesh. 1908-1913.

	July.		August.		September.		October.		November.		December.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
3·5	3	0·30	—	—	—	—	—	—	—	—	—	—
4·5	51	5·17	—	—	2	0·13	8	0·29	70	0·99	419	1·91
5·5	71	7·20	—	—	89	5·79	83	2·99	1,027	14·66	4,087	19·08
6·5	12	1·22	—	—	296	19·27	140	5·04	1,637	23·37	8,845	41·40
7·5	4	0·41	1	0·71	283	18·43	134	4·82	1,965	28·06	5,312	24·81
8·5	47	4·76	1	0·71	137	8·91	41	1·48	1,147	16·38	1,846	8·64
9·5	124	12·57	2	1·42	66	4·30	85	2·99	460	6·57	466	2·18
10·5	117	11·87	10	7·09	32	2·08	266	9·58	191	2·73	130	0·61
11·5	135	13·69	10	7·09	36	2·34	369	13·28	140	1·99	103	0·48
12·5	104	10·54	5	3·55	40	2·60	373	13·43	71	1·01	39	0·18
13·5	77	7·82	11	7·80	90	5·86	434	15·63	46	0·65	21	0·10
14·5	36	3·65	10	7·09	99	6·44	300	10·80	47	0·67	12	0·06
15·5	36	3·65	30	21·27	134	8·72	238	8·57	39	0·56	23	0·11
16·5	22	2·23	19	13·48	86	5·60	131	4·72	49	0·70	13	0·06
17·5	33	3·35	3	2·13	55	3·58	73	2·63	39	0·56	7	0·03
18·5	32	3·24	15	10·64	23	1·49	37	1·33	20	0·28	6	0·03
19·5	27	2·74	10	7·09	21	1·37	21	0·76	16	0·23	2	0·00
20·5	22	2·23	6	4·26	11	0·71	19	0·68	12	0·17	5	0·02
21·5	15	1·52	4	2·84	11	0·71	14	0·50	12	0·17	6	0·03
22·5	9	0·91	—	—	11	0·71	6	0·16	5	0·07	4	0·02
23·5	7	0·71	3	2·13	7	0·45	2	0·07	3	0·04	10	0·05
24·5	2	0·22	1	0·71	6	0·39	3	0·08	3	0·04	5	0·02
25·5	—	—	—	—	1	0·06	—	—	4	0·06	2	0·00
Totals	986	100·00	141	100·01	1,536	99·94	2.777	99·83	7,003	99·96	21,363	99·82

Table XXI. Beaumaris and Red Wharf Bays, 6-inch mesh. 1908-1913.

	January.		June.		July.		August.		September.		October.		November.		December.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
10·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
11·5	—	—	—	—	—	—	—	—	3	0·06	—	—	—	—	—	—
12·5	—	—	—	—	2	0·10	2	0·10	8	0·16	3	0·03	—	—	1	0·04
13·5	4	0·29	2	0·09	1	0·05	3	0·15	20	0·39	14	0·15	5	0·08	2	0·08
14·5	9	0·67	3	0·15	3	0·16	3	0·15	68	1·33	76	0·87	29	0·49	10	0·40
15·5	28	2·07	32	1·58	26	1·43	12	0·59	158	3·10	421	4·84	146	2·45	20	0·79
16·5	43	3·21	92	4·53	43	2·37	51	2·83	291	5·70	1197	13·79	350	5·88	66	2·61
17·5	63	4·70	213	10·49	124	6·84	145	7·19	438	8·58	1493	17·17	413	6·94	94	3·72
18·5	81	6·04	261	12·85	207	11·40	231	11·46	396	7·76	1155	13·28	360	6·05	158	6·25
19·5	91	6·79	259	12·76	273	15·03	318	15·77	430	8·43	802	9·23	343	5·76	175	6·92
20·5	70	5·22	237	11·68	255	14·04	282	13·98	392	7·68	579	6·66	341	5·73	218	8·63
21·5	82	6·12	153	7·54	216	11·91	260	12·90	319	5·70	502	5·77	362	6·08	201	8·05
22·5	85	6·34	113	5·57	156	8·59	170	8·43	342	6·70	405	4·66	345	5·80	224	8·86
23·5	69	5·15	77	3·79	113	6·22	127	6·30	296	5·79	310	3·56	339	5·69	211	8·35
24·5	60	4·48	75	3·69	86	4·73	105	5·21	337	6·60	268	3·08	363	6·10	162	6·41
25·5	69	5·15	64	3·15	65	3·58	67	3·32	299	5·86	261	3·00	349	5·86	154	6·09
26·5	78	5·82	47	2·31	42	2·31	50	2·48	286	5·60	275	3·16	336	5·64	152	6·01
27·5	84	6·27	52	2·56	37	2·04	37	1·83	278	5·44	219	2·52	312	5·24	117	4·63
28·5	67	5·00	56	2·76	36	1·98	34	1·69	217	4·25	215	2·47	361	6·06	120	4·75
29·5	67	5·00	47	2·31	31	1·35	29	1·44	153	2·99	161	1·85	341	5·73	81	3·21
30·5	68	5·07	44	2·17	23	1·21	26	1·29	131	2·56	107	1·23	272	4·59	109	4·31
31·5	62	4·63	45	2·22	17	0·93	20	0·99	85	1·66	81	0·92	176	2·96	68	2·69
32·5	44	3·28	56	2·76	18	0·99	15	0·74	59	1·16	52	0·59	137	2·30	59	2·33
33·5	28	2·09	37	1·82	14	0·77	7	0·35	37	0·73	39	0·45	73	1·23	29	1·15
34·5	34	2·54	19	0·94	7	0·38	6	0·29	22	0·43	22	0·25	60	1·01	28	1·11
35·5	14	1·04	16	0·79	8	0·44	1	0·05	17	0·33	12	0·14	38	0·64	15	0·59
36·5	16	1·19	8	0·39	5	0·27	3	0·15	7	0·14	12	0·14	30	0·50	12	0·47
37·5	2	0·15	6	0·29	2	0·10	2	0·10	7	0·14	4	0·05	14	0·23	8	0·32
38·5	4	0·29	5	0·24	6	0·32	2	0·10	3	0·06	4	0·05	8	0·13	12	0·47
39·5	5	0·37	6	0·29	—	—	1	0·05	1	0·02	2	0·02	14	0·23	10	0·40
40·5	3	0·22	5	0·24	—	—	1	0·05	4	0·08	1	0·01	14	0·23	6	0·24
41·5	2	0·14	—	—	1	0·10	—	—	—	—	3	0·03	6	0·10	4	0·16
42·5	1	0·07	—	—	—	—	—	—	—	—	—	—	2	0·03	1	0·04
43·5	1	0·07	—	—	—	—	—	—	—	—	2	0·02	1	0·01	—	—
44·5	1	0·07	—	—	—	—	—	—	—	—	—	—	2	0·02	—	—
45·5	2	0·14	—	—	—	—	—	—	—	—	—	—	4	0·04	—	—
46·5	1	0·07	—	—	—	—	—	—	—	—	1	0·01	1	0·01	—	—
47·5	1	0·07	—	—	—	—	—	—	—	—	—	—	3	0·05	—	—
48·5	1	0·07	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Totals ...	1340	98·89	2030	99·96	1817	99·74	2016	99·98	5104	99·43	8697	99·98	5950	99·99	2527	100·08

Table XXII. Ages of Plaice measured during October to March, 1908-1913. Sex not considered in the groupings.

Mean length.	0		I.		II.		III.		IV.		Totals.
	No.	%	No.	%	No.	%	No.	%	No.	%	
4·5	20	2·19	—	—	—	—	—	—	—	—	20
5·5	187	20·47	—	—	—	—	—	—	—	—	187
6·5	310	33·95	4	0·18	—	—	—	—	—	—	314
7·5	245	26·83	13	0·58	—	—	—	—	—	—	258
8·5	114	12·46	9	0·40	—	—	—	—	—	—	123
9·5	21	2·30	33	1·48	—	—	—	—	—	—	54
10·5	12	1·31	39	1·75	2	0·06	—	—	—	—	53
11·5	4	0·44	91	4·07	2	0·06	—	—	—	—	97
12·5	—	—	117	5·24	8	0·26	—	—	—	—	125
13·5	—	—	100	4·48	6	0·20	—	—	—	—	106
14·5	—	—	111	4·97	13	0·43	—	—	—	—	124
15·5	—	—	209	9·36	45	1·49	—	—	—	—	254
16·5	—	—	347	15·52	127	4·22	—	—	—	—	474
17·5	—	—	381	17·06	240	7·97	—	—	—	—	621
18·5	—	—	339	15·18	384	12·77	3	0·81	—	—	726
19·5	—	—	193	8·64	414	13·76	19	5·15	—	—	626
20·5	—	—	114	5·10	386	12·83	19	5·15	—	—	519
21·5	—	—	52	2·33	363	12·06	29	7·86	—	—	444
22·5	—	—	28	1·25	299	9·93	21	5·69	—	—	348
23·5	—	—	24	1·07	233	7·74	20	5·42	—	—	277
24·5	—	—	13	0·58	163	5·42	28	7·59	—	—	204
25·5	—	—	4	0·18	115	3·82	26	7·05	1	2·08	146
26·5	—	—	1	0·04	76	2·52	27	7·31	1	2·08	105
27·5	—	—	2	0·09	57	1·89	33	8·94	—	—	92
28·5	—	—	1	0·04	28	0·93	27	7·31	2	4·17	58
29·5	—	—	4	0·18	21	0·69	33	8·94	6	12·50	64
30·5	—	—	3	0·12	9	0·33	23	6·23	5	10·41	40
31·5	—	—	1	0·04	10	0·33	17	4·61	6	12·50	34
32·5	—	—	—	—	5	0·17	19	5·15	1	2·08	25
33·5	—	—	—	—	1	0·03	8	2·17	2	4·17	11
34·5	—	—	—	—	2	0·06	8	2·17	8	16·66	18
35·5	—	—	—	—	—	—	3	0·81	7	14·60	10
36·5	—	—	—	—	—	—	2	0·54	2	4·17	4
37·5	—	—	—	—	—	—	1	0·27	2	4·17	3
38·5	—	—	—	—	—	—	3	0·81	2	4·17	5
39·5	—	—	—	—	—	—	—	—	1	2·08	1
40·5	—	—	—	—	—	—	—	—	—	—	—
41·5	—	—	—	—	—	—	—	—	2	4·17	2
Totals	913	99·95	2,233	99·93	3,009	99·97	369	99·98	48	100·01	6,572

Table XXIII. Sex and Age of Plaice measured in 1908-1913.

Mean length.	I. ♂ No.	I. ♂ %	I. ♀ No.	I. ♀ %	II. ♂ No.	II. ♂ %	II. ♀ No.	II. ♀ %	III. ♂ No.	III. ♂ %	III. ♀ No.	III. ♀ %	IV. ♂ No.	IV. ♂ %	IV. ♀ No.	IV. ♀ %	Totals.
9·5	2	0·22	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
10·5	1	0·11	5	0·58	—	—	—	—	—	—	—	—	—	—	—	—	6
11·5	3	0·33	7	0·82	—	—	—	—	—	—	—	—	—	—	—	—	10
12·5	13	1·45	6	0·70	—	—	—	—	—	—	—	—	—	—	—	—	19
13·5	12	1·04	12	1·40	—	—	—	—	—	—	—	—	—	—	—	—	24
14·5	26	2·90	18	2·10	2	0·14	1	0·09	—	—	—	—	—	—	—	—	47
15·5	83	9·06	79	9·24	18	1·54	17	1·15	—	—	—	—	—	—	—	—	197
16·5	156	17·43	170	19·87	69	4·70	54	3·64	—	—	—	—	—	—	—	—	449
17·5	198	22·13	180	21·05	144	9·80	95	6·41	—	—	—	—	—	—	—	—	617
18·5	177	19·77	162	18·94	194	13·22	185	12·48	2	1·13	1	0·52	—	—	—	—	721
19·5	108	12·07	85	9·94	196	13·36	213	14·37	7	3·95	12	6·25	—	—	—	—	621
20·5	60	6·70	54	6·32	193	13·15	188	12·69	8	4·52	11	5·73	—	—	—	—	514
21·5	31	3·46	21	2·46	167	11·39	196	13·22	13	7·33	16	8·33	—	—	—	—	444
22·5	10	1·12	18	2·10	140	9·54	157	10·59	5	2·24	16	8·33	—	—	—	—	346
23·5	9	1·01	15	1·75	106	7·22	127	8·57	12	6·62	8	4·16	—	—	—	—	277
24·5	5	0·56	8	0·93	69	4·70	94	6·34	14	7·91	14	7·29	—	—	—	—	204
25·5	1	0·11	3	0·35	53	3·61	62	4·18	18	10·17	8	4·16	1	3·33	—	—	146
26·5	—	—	1	0·12	41	2·79	35	2·37	13	7·33	14	7·29	1	3·33	—	—	105
27·5	—	—	2	0·23	40	2·73	17	1·15	17	9·60	16	8·32	—	—	—	—	92
28·5	—	—	1	0·12	15	1·02	13	0·88	14	7·91	13	6·77	2	6·66	—	—	58
29·5	—	—	4	0·46	10	0·68	11	0·74	15	8·47	18	9·38	5	16·66	1	5·55	64
30·5	—	—	3	0·34	2	0·14	7	0·47	14	7·91	9	4·68	5	16·66	—	—	40
31·5	—	—	1	0·11	3	0·20	7	0·47	6	3·39	11	5·73	3	10·00	3	16·66	34
32·5	—	—	—	—	3	0·20	2	0·18	8	4·52	11	5·73	1	3·33	—	—	25
33·5	—	—	—	—	—	—	1	0·09	5	2·82	3	1·56	—	—	2	11·11	11
34·5	—	—	—	—	2	0·14	—	—	2	1·13	6	3·13	4	13·33	4	22·22	18
35·5	—	—	—	—	—	—	—	—	3	1·69	—	—	4	13·33	3	16·66	10
36·5	—	—	—	—	—	—	—	—	—	—	2	1·04	1	3·33	1	5·55	4
37·5	—	—	—	—	—	—	—	—	—	—	1	0·52	2	6·66	—	—	3
38·5	—	—	—	—	—	—	—	—	—	—	2	1·04	1	3·33	1	5·55	4
39·5	—	—	—	—	—	—	—	—	1	1·13	—	—	—	—	1	5·55	2
40·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
41·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	11·10	2
Totals	895	99·43	855	99·93	1,467	100·27	1,482	100·08	177	99·77	192	99·96	30	99·95	18	99·95	5,116

Table XXIV. Modal Lengths of Plaice measured during 1908-1913.

	6-inch trawl-mesh.				½-inch trawl-mesh.
	Blackpool to Liverpool Bar.	Horse Channel.	Beaumaris and Red Wharf Bays.	Luce Bay.	Mersey Estuary.
Jan. ...	—	—	20·6, 28 (25·04)	—	7
Feb. ...	—	—	—	—	8·2
Mar. ...	—	—	—	—	8·5
April ...	—	19·6	—	—	7, 14·2
May ...	17·2	19·8	—	—	15·6
June ...	19	18·8	19·5	—	10, 14·6
July ...	19·8	20	20·6	—	5·3, 11·6, 19·4
Aug. ...	20·2	21·4	20·4	—	12, 16, 19·2
Sept. ...	20	21·5	19·2, 25·4 (22·7)		7·7, 15·6
Oct. ...	18·4, 24 (21·03)	21	18, 28·4 (20·5)	20·6, 30,	7·3, 13
Nov. ...	—	—	18·5, 30·8 (24·0)	34 (26·84)	7·6
Dec. ...	—	—	22·2 (24·16)		7·2

NOTE.—Numbers in brackets are means.

Table XXV. Mean Values of the Length-Weight Coefficient *k*. 1908-1913.

	Morecambe Bay.	Near Nelson Buoy.	Mersey Estuary.	Beaumaris and Red Wharf Bays.	Menai Straits.	Means.
Jan. ...	0·907	—	0·866	—	—	0·886
Feb. ...	0·973	—	0·838	—	0·972	0·927
Mar. ...	0·941	—	0·834	—	0·836	0·870
April ...	1·006	—	0·874	—	—	0·940
May ...	0·974	0·950	1·006	0·950	—	0·970
June ...	1·14	0·980	0·980	1·015	—	1·029
July ...	1·17	1·031	1·074	0·985	—	1·085
Aug. ...	—	1·024	1·067	0·954	—	1·015
Sept. ...	1·06	1·022	1·063	1·005	—	1·037
Oct. ...	1·03	1·028	0·977	1·035	0·955	1·005
Nov. ...	0·949	1·07	0·999	1·021	0·953	0·998
Dec. ...	—	—	—	0·965	0·855	0·910
Means ...	1·015	1·015	0·961	0·991	0·914	—

REPORT ON THE EXPERIMENTS WITH MARKED FISHES MADE DURING THE YEAR 1913.

By Jas. Johnstone, D.Sc., and T. Monaghan.

(With Tables and Charts.)

The object of the experiments of 1912 and 1913 has been to provide data confirmatory of the former experiments. Plaice have been marked and liberated on the same grounds, and at similar seasons during various years, until a mass of results has been obtained which can be summarised, all the experiments made under the same conditions being grouped together. It is hoped that, in this way, cumulative evidence of the regular yearly migrations, free from any accidental results, may be obtained. When we have such a general picture of the migratory movements of plaice in the Eastern half of the Irish Sea, the results of any single experiment can be considered by themselves, so that the factors of migration peculiar to the season in question can be considered. In 1910 a general summary of the experiments of earlier years was made, with the object of obtaining suggestions for future work. These suggestions have been applied in the experiments of 1912 and 1913, and it is proposed that the same general lines of work be followed in 1914. After that, the deviations from the normal which may be observed in individual experiments may usefully be studied in relation to unusual physical or other conditions.

Throughout the experiments of these and former years the object in view has been simply that of attaining a knowledge of the movements and rate of growth of plaice living in the Lancashire and Western Sea Fisheries Area.

Such an attitude, in studying a problem which seems likely to become one of economic importance, appears to be the best one, if the results expected to be attained are to possess economic importance. The research, in the past, has therefore been a purely abstract one, unhampered by any obligation to obtain results of "practical" value. Nevertheless, one seems to foresee certain directions which legislative restrictions on fishery methods may take in the immediate future. The closure of fishing grounds has been tried in this district and elsewhere with but indifferent success, and the same may be said of the attempt to regulate the dimensions of nets and other fishing gear. After adopting mesh regulations and enforcing these at some considerable expense, and creating acute friction between the fishermen and the fishery officers, this and other Local Committees have been obliged to confess the failure of their policy by the rescinding of some of their bye-laws. In devising and carrying out these experiments, as well as in the organisation of the collection of statistics relating to the sizes of plaice on the fishing grounds, we have, therefore, been influenced by a consideration of the kind of data that may, perhaps, be required when a further period of legislative restriction is entered upon by the fishery authorities. It must be admitted that if even such a limited collection of experimental and statistical results as we now possess had been acquired during the first half-dozen years of the work of the Local Fishery Committees, the legislative restrictions of the last fifteen or so years might have been more successful.

If, then, the imposition of legal size-limits on plaice and other fish landed for sale in this and other parts of the country be attempted, the results presented in these and other reports may be of value. In another paper in this

publication the materials for assessing the probable effects of size-limits in the case of plaice are given. But even when we know what fraction of the total catch of fish made is likely to be affected by the imposition of, say, an eight-inch limit to plaice landed, the problem of the utility of such a regulation is far from being solved. If we prevent fish from being landed, we must also prevent them from being caught. No useful result is attained merely by preventing the capture of plaice of, say, less than eight inches in length: underlying the attempt to prevent these relatively valueless fish from being caught is the assumption that they will grow, in a short time, to be fishes of much greater commercial value. Perhaps some of them may, but it must be pointed out that nothing justifies us in confidently expecting that a considerable proportion of the small plaice saved from capture on a small-fish ground will grow to be medium-sized fish on an adjacent ground. Before we embark on legislative restrictions affecting the practice of the inshore fishermen, we ought to be sure that the loss to these men will be much more than balanced by the gain which other kinds of fishermen will experience. And even when we are quite sure that this gain will be attained, the further social-economic problem arises as to whether we are justified in adopting legislation that is designed to operate by transferring a profitable fishery from one poorer, to another richer, class of fishermen. This, of course is a problem with which, as investigators, we have nothing to do.

Putting the question in as concrete a form as we can, the points to be considered seem to be these:—Between Nelson Buoy and Liverpool Bar there is a summer and autumn plaice fishery, in the course of which about one-half of all the fish caught by a trawl net of six-inch mesh are under eight inches in length. There is a market for

this class of fish—otherwise the half-decked trawling vessels would hardly catch and land them. If we prevent the landing of plaice of less than eight inches from this area, we ought to expect that the fish will migrate, or will hibernate, until another season, when their average length will be some two inches more, and when they will almost have doubled in weight. *Then* they ought to be caught on either the same or some other ground as larger and more valuable fish. It is not at all likely that these small plaice will be caught next season on the same ground as larger plaice—it seems to us to be far more likely that the adoption of such a size-limit would, in the case of the Nelson Buoy grounds tend to *reduce* the average size; provided that our assumption that the fish remain there, or closer inshore, during the winter months is true. But the small fish may grow and migrate from these grounds if they are not caught: let it be supposed that they will grow and migrate on to the winter fishing grounds off the coasts of Anglesey and Carnarvon. Then we shall have saved plaice of, say, three ounces in average weight from being caught by the second-class sailing trawlers in order that they may be caught by first-class sailing trawlers as fish of, say, eight to ten ounces in average weight. But this argument assumes that all, or a great proportion, of the small plaice on the Nelson Buoy grounds do grow and migrate, and this is obviously a hypothesis with regard to which we require proof.

It is, then, considerations of such a kind as we have mentioned above that have, to some extent, influenced us in devising and carrying out these marked fish experiments. The results so far attained, and likely to be attained, in the continuance of the experiments, will go far to provide data for a rational discussion of the probable effects of the restrictions contemplated, and may prevent

the adoption of the futilities in the way of bye-laws, of which the past of fishery regulation affords numerous examples.

The Experiments of 1913.

Six experiments in all were made in 1913. In March about 100 flounders and plaice were caught by the Fleetwood police cutter, and put into the tanks in the Piel Hatchery. Eighty of these fish, 70 flounders and 10 plaice, were marked after they had been in the tanks for a week

General Summary of the Experiments of 1913 and their results.

No. of experiment.	Place where the fishes were liberated.	Date of experiment.	No. of fishes liberated.	No. recaught.	% recaught.
I.	Near Piel Gas Buoy (54°N., 3°13′W.)	Mar. 13, 1913	70 flounders 10 plaice	14 3	20 33
II.	Entrance to Barrow Channel (54°4′N., 3°10′W.)	April 22, 1913	177 plaice 18 flounders	77 4	43·5 22
III.	Blackpool Closed Ground (53°50′N., 3°10′W.)	June 30, 1913	133 plaice 1 sole	17	12
IV.	Near Nelson Buoy (53°41′N., 3°15′W.)	July 17, 1913	65 plaice	3	5
V.	Near Nelson Buoy (53°41′N., 3°15′W.)	Sept. 17, 1913	283 plaice 14 soles	55 1	19·5 0·5
VI.	Beaumaris Bay (53°22′N., 3°58′W.)	Nov. 20, 1913	220 plaice	57	26
Total			991	231	23·3

Experiments of 1912. Additional Records.

No. of experiment.	Recaptures already recorded.	Recaptures in 1913.	No. of fishes liberated.	No. recaught.	% recaught.
I.	26	3	212	29	13
II.	26	16	153	42	27
III.	1	5	45	6	13

or so. The fish were liberated at Piel Gas Buoy. In the second experiment of the year the same methods were adopted: the fish were caught and put into the Piel tanks, where they were marked. This lot of plaice and flounders were liberated in Barrow Channel about half-way between Piel and Walney Point, that is, they were put out on approximately the ground where they were caught. Experiments III, IV, and V relate to the plaice found on the small-fish grounds about Nelson Buoy, and in them 481 plaice and 15 soles were marked and liberated. It was thought desirable to deal with different lots of plaice in different months rather than with one much larger lot in one particular month: in this way it became possible to study the different migration paths taken at different times in the year. Finally, Experiment VI was made in Red Wharf and Beaumaris Bays in November, the fish being caught and marked just before the winter fishery on these grounds had attained its full dimensions. In Experiments III to VI the fish were caught, marked and liberated on the S.S. *James Fletcher*.

An attempt was made to mark soles. This had previously been attempted, using the same mark as in the case of plaice, but the results were quite unsuccessful. In 1913 we got some 50 special labels made. Each was a strip of thin sheet silver about 1 cm. in width and about 2 cms. in length. At one end of this strip a little tongue of metal projected out, and was then turned up at right angles to the surface of the strip; at the other end was a little hole. The strip was bent on itself so that the little tongue fitted into the hole. Each label was marked L 1 to L 50. It was fixed to the fish by clasping it on the free border of the operculum on the coloured side, squeezing the bent strip of silver by means of pliers until the tongue was forced through the opercular edge into the hole on the

other end of the strip. The labels were obtained towards the end of the season, so that it was only possible to make one experiment, and then only 14 soles were marked. So far only one of these fish has been recaught, so that it is impossible to say whether or not the method is likely to become a successful one. We may now say something about each experiment.

Experiment I. (Chart I.)

Seventy flounders were marked and liberated, but

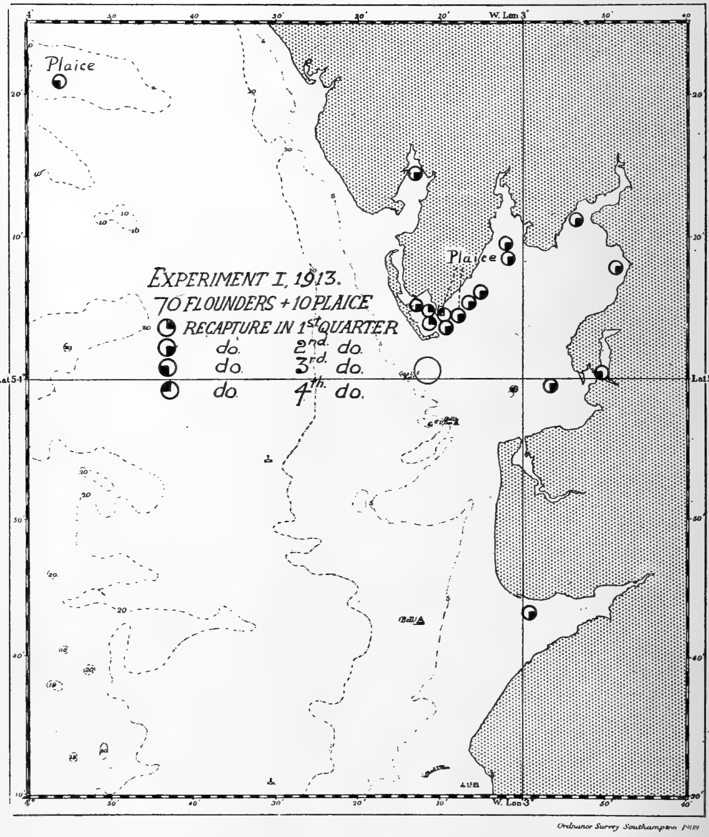


FIG. 1. Experiment I, 1913.

only 14 of these were returned to us. The results are hardly susceptible of being made into a general theory of flounder migrations until further experiments on a larger scale have been made. So far as they and former experiments with flounders go, they indicate that this fish migrates mainly along the shallow coastal waters. Possibly the larger fish may migrate out to sea at the end or the beginning of the year, since fairly large flounders in a sexually ripe condition are often found on the offshore grounds. At any rate, the experiments must be repeated before we can say much. The flounder, however, is of so little economic importance that we have hitherto hesitated to spend much time on its study, so long as the more important plaice could be investigated.

Experiment II. (Chart II.)

The results of this experiment are rather remarkable, and they seem to us to be of some value. The number of plaice liberated was 177, of which 77, or over 43 %, were recaught and returned to us, a rather large proportion, so far as most marked-fish experiments are concerned. Eighteen flounders were also marked, and of these four were returned. Sixty-four of all these plaice and flounders were caught in stake-nets set in Barrow Channel and on Roosebeck Scars (just outside Barrow Channel), and the rest were taken by second-class trawling vessels, five of them being recaptured by the Fleetwood police cutter, which had originally caught the fish for the marking experiment. The fish taken in the stake nets were caught by two or three men at the most, fishing each a stake-net for a few tides during each fortnight. The results are shown on Chart II, but because of the small scale on which the chart has had to be drawn, and the limited area over which the recaptures have been made,

it has not been possible to represent accurately the position of each recapture. One plaice was recaptured in the Estuary of the Duddon, and another near Liverpool Bar. With these exceptions the fish recaught appear to have

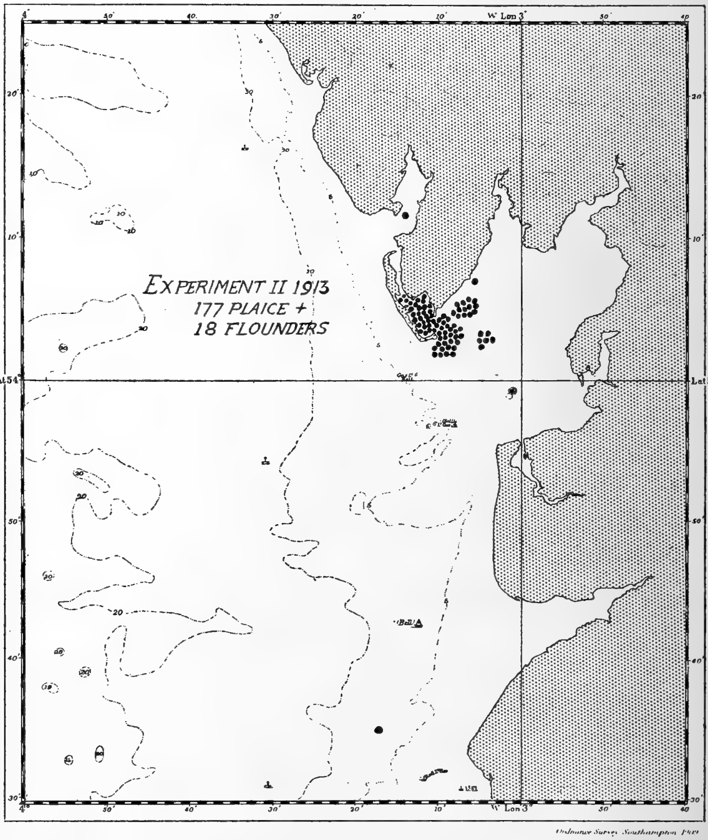


FIG. 2. Experiment II, 1913.

been generally distributed over the greater part of the fishing grounds in Barrow Channel within the range of stake-nets and second-class trawling vessels. The experiment was made on 22nd April, and the majority of the

fish were recaptured during the months of April, May, and June; yet, even in December of the same year, two of these plaice were recaught in Barrow Channel.

Now it is perhaps as well that not too much importance should be attached to the measures of "intensity of fishing" deduced from marked fish experiments. It has been claimed that if (say) 25 % of the fish liberated in some particular experiment are recaught within (say) one year, then 25 % of all the fish inhabiting the area fished over by the boats, among which were they that recaught the marked fishes, must also have been caught. That is, the percentage of the marked fish recaught is also the percentage of all the fish caught. This conclusion would be, generally speaking, a reliable one if all the fish marked and liberated survived in a healthy condition, and if they were evenly distributed over the area fished commercially. Usually this is not the case, and in so far as some of the fish marked are injured and do not survive, and all are unevenly distributed, so far does the argument lose its force.

In this particular case the plaice were liberated in a narrow channel with such a great rise and fall of tide that the area covered by the sea varies enormously. The tidal streams are very rapid. The trawlable area, and that over which stake nets are set, are restricted, that is, only a rather small part of the navigable channel is trawled, and there are very few places on which stake nets are usually set. The fishermen do not, then, go to look for the fish; they do not change their fishing grounds as the fish are more or less abundant. They wait for the fish to come to their nets, so to speak. In these circumstances it seems as if they really did sample a fish population, which moved about over the whole of the area, according to the tides. The fish marked were selected,

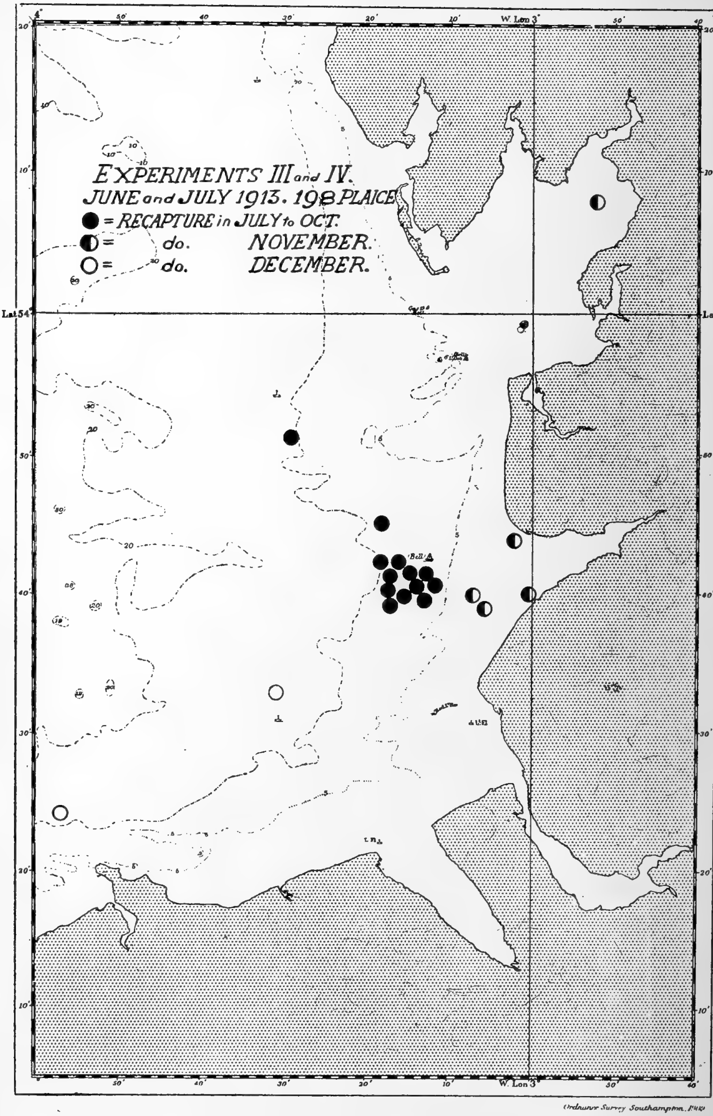


FIG. 3, Experiments III and IV, 1913.

that is, only those that had lived in the Piel tanks for some weeks after capture were marked, and when liberated they were in very good condition. Altogether it would seem as if the results of this experiment do roughly give us an idea as to the extent to which the operations of about a dozen fishermen using stake-nets and second-class trawling vessels sampled a stationary population; that is, a plaice population which entered Barrow Channel at the beginning of 1913, which did not leave it during the greater part of the year, and which was not recruited from external regions throughout the same period.

Experiments III and IV. (Chart III.)

These may be taken together. The former was made in June, and the latter in July, and 17 fishes from the first experiment were recovered, while only three from the latter came back to us. There are three groups of recoveries, (1) fish which have moved further offshore from the place of liberation during the months July to October; (2) fishes which have migrated further inshore during November; and (3) fish which have moved to the westward, toward the winter grounds off the coasts of Anglesey and Carnarvon during December. This latter group is represented by only two recaptures, and the second group by only five recaptures, but the facts are significant since they are similar to those of other corresponding experiments.

Experiment V. (Chart IV.)

Quite good results were obtained from this experiment. The fishes marked and liberated were 283 plaice and 14 soles. Fifty-five of the former and one sole were returned. The sole was caught only a few days after the date of liberation, so that this single result does not give much information as to the value of the method of marking.

Just the same three groups of recaptures were obtained in this as in the last experiment. (1) There are a large number of plaice recaught in the immediate neighbourhood of Nelson Buoy, the place of liberation. The scale

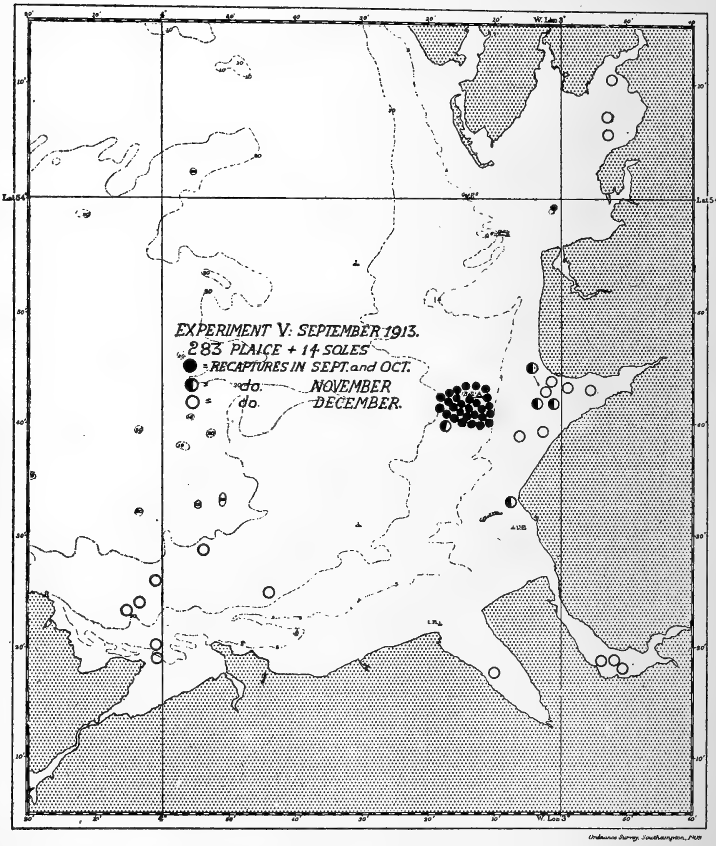


FIG. 4. Experiment V, 1913.

of the chart is so small that it has been difficult to assign the symbol representing each of these recaptures to its exact position: this group of recaptures really occupies a rather more restricted position on the chart than has been

indicated. All these fish were recaught in September and October, months during which there is still an active fishery in the neighbourhood of Nelson Buoy. (2) A group of 16 plaice have migrated inshore during the month of November, and have been recaught in all the great Bays and Estuaries from the Dee to the Kent in Morecambe Bay. (3) Seven fish have made the migration to the westward, to the winter fishing ground in the Red Wharf-Beaumaris Bays area. These are precisely the same kinds of migrations which were made by the recaptured fishes of Experiments III and IV, and by those of former years' experiments in this area and at this season of year.

Experiments I and II of 1912. (Chart V.)

Along with the results of Experiment V of 1913 it will be convenient to consider those of Experiments I and II of 1913, since to the recaptures of 1912 have been added the additional ones relating to this experiment, but recorded in 1913. We see then the same general results as those of the present year, but there is the difference that the fish recaptured during the months July to September, while still moving offshore in the same general way as in 1913, have distributed themselves more widely over the sea to the West from Nelson Buoy: in 1913 the shoal remained relatively concentrated when compared with the distributions of former years. This represents the kind of deviation which may be studied and correlated with the physical conditions of the season, when once we have attained a generalised knowledge of the migratory paths and seasons corresponding to the average conditions. In October the recaptures seem to indicate the inshore movement, that is, the fishes recaptured in that month have been found, on the whole, closer inshore than in the previous months. Then we have the winter migrations

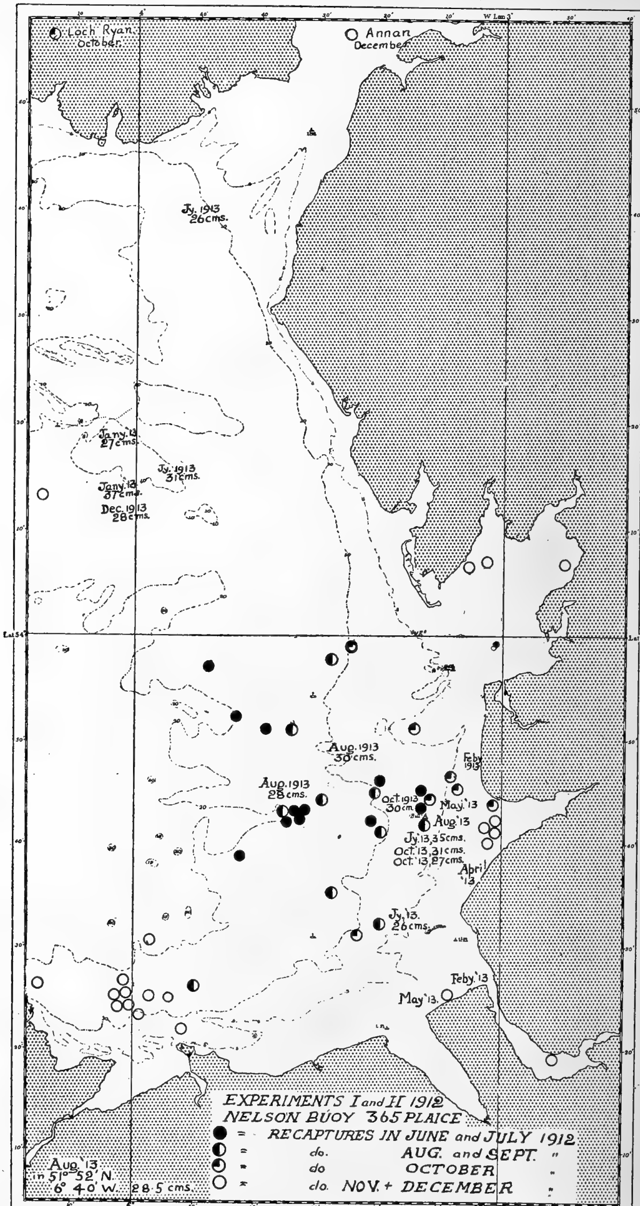


Fig. 5. Experiments I and II, 1912.
Dates indicate the positions of recapture in 1913, symbols those of 1912.

proper, that is, those made in November and December, and we find the same division of these into the group of fishes which have moved into the Bays and Estuaries, and those which have moved westward into Red Wharf Bay and adjacent regions. It is probable that when sufficient data have accumulated we shall find that the size, or perhaps age, of the fishes in these two groups varies, and that the general nature of the migrations made by the plaice abandoning the Nelson Buoy grounds is determined to some extent by the age to which they have attained, perhaps also by their "condition." These comparisons and groupings of the data have yet to be made and all the material exists in the card records of the results of the experiments.

Adding to the results of the year of liberation those of the year following, we get some further information. The recaptures of 1913 are indicated on the chart by the name of a month (that of recapture), the date "'13," and usually the size of the fish when it was recaptured. We see now that few, if any, fish migrate from the Nelson Buoy area into the Red Wharf one after the end of the year. On the other hand, one fish had migrated to the sea just East from the North-end of the Isle of Man (the Bahama Bank grounds we may call this), and three have made the same migration during the January immediately following. A few fish were found during the first six months of the year along the Lancashire and Cheshire coasts, and some were found on the Nelson Buoy grounds themselves during the summer and autumn of the year following that of liberation: these were probably plaice that had moved into the inshore waters, and had then migrated out again about the beginning of the summer of the following year.

Considering even these two years' experiments alone,

we can give the following general scheme of movements of plaice in Lancashire water. (1) There are practically no regular migratory movements of plaice under about eight inches in length. These fish live, for the most part, in the shallow intra-territorial waters, particularly in the shallower channels. They move about irregularly, the direction and extent of the movements depending on the tidal streams; on slight temperature changes produced by tidal streams ebbing off the land, or flowing in from the open sea, or by freshets coming down from the rivers; and on the individual "caprice" of the fish themselves. They do not migrate "in search" of food, but moving about irregularly they encounter accidentally food, such as beds of young mussels or other shell-fish, and having "struck" the food, they remain in its locality: a shoal of plaice thus gradually forms. This is all that we can say about the movements of plaice of the smaller range of sizes. Then in the early spring and summer these fish begin to grow with the increasing temperature of the water. But the latter soon exceeds its mean, or perhaps late spring value —a value which is probably the optimal one for these fishes. A migration offshore, that is in such a direction as to compensate for the rise of temperature inshore, now begins, the fish endeavouring to enter water of lower temperature. In this way the shoals of plaice which form round Nelson Buoy, between here and Liverpool Bar, or in the channels and off the banks out from the Estuaries of the Dee and Mersey, are formed, and thus the summer fisheries in these regions become established. They continue until the temperature of the water falls below the optimal value in the late autumn, and then the shoals break up. The smaller fishes migrate inshore, probably there is a range of water pressure which their habitats do not exceed. They hibernate to some extent

during the winter months by burrowing in the sand, being shifted possibly by the disturbance of the latter due to strong tidal streams during the times of the springs. The medium-sized fish migrate down to the westward, that is, into the warmer waters of Red Wharf Bay and its vicinity: while the largest of all may migrate to spawn in the neighbourhood of Bahama and the other Banks eastward from the Isle of Man. This is a general scheme which may be amended in detail by a close analysis of all the observations to be accumulated by a year or two of further work; and the deviations from which may be explained by irregularities in the annual cycles of physical changes in the sea.

Experiment VI. (Chart VI.)

We have finally to consider the results of the only winter experiment made during 1913. In November 220 plaice were marked and liberated off Beaumaris and Llandudno Bays. Fifty-seven of these fishes—that is, 26 % were recaptured before the end of the year. It will be seen from Chart VI that most of these plaice were recaught very near the place of liberation—a result which has always attended the experiments made in this locality. With the end of the year these recaptures usually cease, the plaice having then abandoned the North Wales fishing grounds. It is not quite the result which we wish to attain—that of the immediate recapture of the fish in the region of liberation, but the fishery in question is one which may come to an end before the end of the year; and the precise times at which one may carry out the marking operations are dependent on other circumstances than one's own judgment as to the best times. A large number of plaice must, therefore, be marked and liberated before we can say with confidence what is

the fate of the fish which migrate out from the Red Wharf-Beaumaris Bays area at the end of the year, and this result is attainable by the summation of successive annual experiments. We can depend on the conditions and migrations being very much the same from year to year.

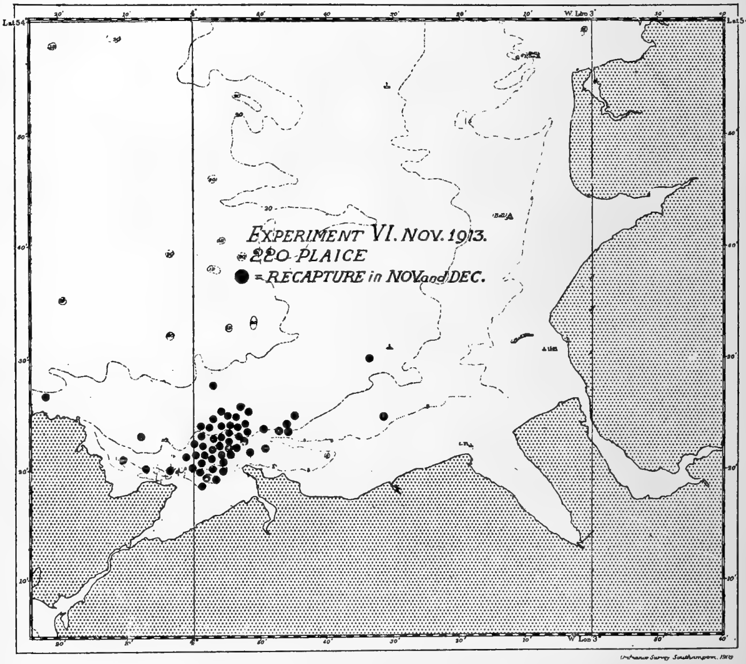


Fig. 6. Experiment VI, 1913.

Slight deviations do, as we have indicated elsewhere, occur: for instance, the grouping of the recaptures from the experiment of 1913 to the North-West of Great Orme's Head is not always the case. In some former experiments the bulk of the fish have been taken in and immediately off Red Wharf Bay.

Probably a considerable proportion of the larger plaice

which inhabit this area migrate round Anglesey to the southern part of St. George's Channel, while others go to the North towards the Bahama Bank area. What is the proportion of fish taking part in these movements has still to be ascertained by further experiments and the collating of all the results.

In the tables which follow we have arranged the data just as in former years. In addition to the particulars published, the sex, weight, age, and phase of maturity of the fishes returned have been determined, and are recorded on the cards giving the history of each particular fish. These data have hardly at all been considered so far: obviously some general ideas as to the possible use of the material must be attained before the labour of a detailed analysis of all the data is undertaken.

The methods of recapture of the fishes are given in the last column:—"SN" means stake-net, "1T," first-class trawler, "2T," second-class trawler, "ST," steam trawler, "GN" and "FN," mean gill-net and flounder-net, methods of fishing practised in Luce Bay. A few recaptures denoted by "PC" were made by the Fleetwood Police Cutter trawling in Barrow Channel. This year, for the first time, the S.S. "James Fletcher" recaptured a plaice which had originally been liberated from that vessel.

Experiment I. 1913.

70 Flounders and 10 Plaice. Liberated Piel Gas Buoy, March 13th, 1913. Nos. LA 503-582.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 554F	23·5	Barrow Channel, near Big Pier	54° 4′ N. 3° 11′ W.	28.3.13	23·5	0	SN
LA 573P	20·5	Barrow Channel	54° 4′ N. 3° 11′ W.	28.3.13	20·5	0	SN
LA 552F	23	Barrow Channel, Roosebeck	54° 6′ N. 3° 7′ W.	10.4.13	23	0	SN
LA 548F	24	Barrow Channel, Roosebeck	54° 6′ N. 3° 7′ W.	11.4.13	24·5	½	SN
LA 532F	23	Barrow Channel	54° 4′ N. 3° 11′ W.	1.5.13	23	0	2T
LA 525F	22	S. side of Ribble, opposite top end of Lytham	53° 44′ N. 2° 59′ W.	2.5.13	22·5	½	SN
LA 580P	17	Barrow Channel, Roosebeck	54° 6′ N. 3° 7′ W.	2.5.13	17	0	SN
LA 517F	30	Barrow Channel	54° 4′ N. 3° 11′ W.	5.5.13	30	0	SN
LA 559F	16·5	½ mile from Chapel Island	54° 9′ N. 3° 2′ W.	9.5.13	17	½	SN
LA 510F	20	1 mile S. of Foxfield, Duddon Channel	54° 15′ N. 3° 13′ W.	19.5.13	20	0	SN
LA 531F	21·5	Sunderland Bank	54° 00′ N. 2° 54′ W.	23.5.13	21·5	0	SN
LA 550F	20	Chapel Island, near Ulverston Channel	54° 10′ N. 3° 2′ W.	29.5.13	—	—	SN
LA 540F	21·5	Morecambe Bay, near Carnforth	54° 8′ N. 2° 49′ W.	4.6.13	23	1½	SN
LA 530F	24	Holme Island, near Grange	54° 13′ N. 2° 55′ W.	10.6.13	24	0	SN
LA 546F	20	Mouth of River Cocker, ¼ mile S. of No. 6 Buoy in River Lune	54° 1′ N. 2° 50′ W.	1.7.13	22	2	SN
LA 577P	18	S. by E. easterly, 5 miles from King William Buoy, 18 fathoms	54° 21′ N. 3° 56′ W.	30.9.13	—	—	ST
LA 534F	21·5	Barrow Channel	54° 4′ N. 3° 11′ W.	9.12.13	—	—	SN

Experiment II. 1913.

177 Plaice and 18 Flounders. Liberated in Barrow Channel, April 22nd, 1913. Nos. LA 583-778.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 593	20	Barrow Channel	54° 4′ N. 3° 11′ W.	23.4.13	20	0	SN
LA 674	20·5	,,	,,	23.4.13	20·5	0	SN
LA 688	22·5	,,	,,	23.4.13	22·5	0	SN
LA 712F	23	,,	,,	23.4.13	23	0	SN
LA 713	18	Roosebeck Scars	54° 6′ N. 3° 7′ W.	24.4.13	18·5	½	SN
LA 722	18	,,	,,	24.4.13	18	0	SN
LA 735	17·5	Barrow Channel	54° 4′ N. 3° 11′ W.	24.4.13	17·5	0	SN
LA 750	17·5	,,	,,	24.4.13	17·5	0	SN
LA 705	21·5	Roosebeck Scars	54° 6′ N. 3° 7′ W.	24.4.13	21·5	0	SN
LA 774	17	Barrow Channel	54° 4′ N. 3° 11′ W.	24.4.13	17	0	SN
LA 596	19·5	,,	,,	24.4.13	19·5	0	SN
LA 620	22·5	Roosebeck Scars	54° 6′ N. 3° 7′ W.	24.4.13	22·5	0	SN
LA 645	20	Barrow Channel	54° 4′ N. 3° 11′ W.	24.4.13	20·5	½	SN
LA 697	19	,,	,,	24.4.13	21	2	SN

Experiment II—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 629	26	Barrow Channel	54° 4′ N. 3° 11′ W.	24.4.13	26·5	½	SN
LA 603*	18·5	,,	,,	25.4.13	—	—	PC
LA 607*	20·5	,,	,,	25.4.13	—	—	PC.
LA 676*	24·5	,,	,,	25.4.13	—	—	PC
LA 733*	18·5	,,	,,	25.4.13	—	—	PC
LA 755	17	,,	,,	26.4.13	17	0	SN
LA 643	21	,,	,,	26.4.13	21	0	SN
LA 638	22·5	,,	,,	26.4.13	22·5	0	SN
LA 699	21·5	,,	,,	26.4.13	21·5	0	SN
LA 698	21	,,	,,	26.4.13	21	0	SN
LA 759	18	,,	,,	28.4.13	19	1	SN
LA 771	19·5	Morecambe Bay	54° 4′ N. 3° 4′ N.	28.4.13	19·5	0	SN
LA 621	19·5	Barrow Channel	54° 4′ N. 3° 11′ W.	29.4.13	19·5	0	SN
LA 751	18	,,	,,	29.4.13	18	0	SN

* These fish were caught by the Police Cutter "Piel Castle," and re-liberated on their respective dates.

Experiment II—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 763	17·5	Morecambe Bay	54° 4′ N. 3° 4′ W.	29.4.13	17·5	0	SN
LA 769	17	,,	,,	29.4.13	17	0	SN
LA 693F	21	Barrow Channel	54° 4′ N. 3° 11′ W.	29.4.13	21	0	SN
LA 682	20	,,	,,	1.5.13	20	0	2T
LA 631	21·5	,,	,,	1.5.13	21·5	0	2T
LA 656	23·5	Roosebeck	54° 6′ N. 3° 7′ W.	2.5.13	23·5	0	SN
LA 691	21·5	,,	,,	2.5.13	21·5	0	SN
LA 702	22	Barrow Channel	54° 4′ N. 3° 11′ W.	2.5.13	22	0	2T
LA 718	17·5	,,	,,	2.5.13	18	½	2T
LA 720	18	Roosebeck	54° 6′ N. 3° 7′ W.	2.5.13	18	0	SN
LA 738	16	Barrow Channel	54° 4′ N. 3° 11′ W.	2.5.13	16	0	SN
LA 744	18	,,	,,	2.5.13	18	0	2T
LA 767	16·5	Morecambe Bay	54° 4′ N. 3° 4′ W.	2.5.13	16·5	0	SN
LA 685	18	Barrow Channel	54° 4′ N. 3° 11′ W.	5.5.13	18	0	SN

Experiment II—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 772	17	Morecambe Bay	54° 4′ N. 3° 4′ W.	5.5.13	17	0	SN
LA 715	19·5	Barrow Channel	54° 4′ N. 3° 11′ W.	5.5.13	19·5	0	SN
LA 732	17	,,	,,	5.5.13	17·5	½	SN
LA 741	17·5	,,	,,	5.5.13	18	½	SN
LA 743	17	,,	,,	5.5.13	17·5	½	SN
LA 595	23·5	,,	,,	5.5.13	23·5	0	SN
LA 737	17·5	Roosebeck	54° 6′ N. 3° 7′ W.	6.5.13	18	½	SN
LA 703	19·5	Barrow Channel	54° 4′ N. 3° 11′ W.	7.5.13	19·5	0	SN
LA 594	18·5	,,	,,	7.5.13	—	—	SN
LA 641	24	,,	,,	7.5.13	—	—	SN
LA 655	22	,,	,,	9.5.13	22·5	½	2T
LA 642	19·5	,,	,,	9.5.13	19·5	0	SN
LA 687	18·5	,,	,,	9.5.13	18·5	0	2T
LA 648	22	,,	,,	9.5.13	22·5	½	2T

Experiment II—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 746	18	Roosebeck	54° 6′ N. 3° 7′ W.	10.5.13	18	0	SN
LA 623	19·5	,, ...	,,	10.5.13	20	½	SN
LA 758	18·5	Barrow Channel	54° 4′ N. 3° 11′ W.	12.5.13	18·5	0	SN
LA 615*F	24	,, ...	,,	13.5.13	—	—	PC
LA 696	19	,, ...	,,	14.5.13	19·5	½	2T
LA 586	18	,, ...	,,	14.5.13	18·5	½	2T
LA 662	26·5	Roosebeck	54° 6′ N. 3° 7′ W.	19.5.13	27	½	SN
LA 630	19·5	,, ...	,,	19.5.13	19·5	0	SN
LA 649	19	,, ...	,,	19.5.13	19·5	½	SN
LA 754	16·5	Barrow Channel	54° 4′ N. 3° 11′ W.	24.5.13	17	½	SN
LA 633	22	,, ...	,,	26.5.13	23	1	SN
LA 775	16	,, ...	,,	26.5.13	16	0	SN
LA 681	18	,, ...	,,	26.5.13	18	0	SN
LA 679	22	,, ...	,,	26.5.13	22	0	SN

* This fish was caught by the Police Cutter "Piel Castle," and re-liberated the same day.

Experiment II—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 608	20	Barrow Channel	54° 4′ N. 3° 11′ W.	26.5.13	20	0	SN
LA 757F	20	1 mile E. from Millom Pier	54° 12′ N. 3° 14′ W.	31.5.13	22	2	SN
LA 665	19·5	Barrow Channel	54° 4′ N. 3° 11′ W.	3.6.13	19·5	0	SN
LA 598	21·5	E. side of Morecambe Bay, near Aldingham	54° 7′ N. 3° 6′ W.	12.6.13	22·5	1	SN
LA 724	18	Barrow Channel	54° 4′ N. 3° 11′ W.	13.6.13	18	0	SN
LA 680	21·5	,,	,,	17.6.13	—	—	SN
LA 756	17·5	,,	,,	22.6.13	17·5	0	SN
LA 667	26·5	Between Elbow Buoy and Ramsden Dock Gates (Barrow Channel)	54° 7′ N. 3° 15′ W.	14.9.13	—	—	2T
LA 714	19	5 miles N.N.W. from Bar Lightship, 15 fathoms	53° 35′ N. 3° 17′ W.	28.10.13	24	5	ST
LA 669	24·5	Barrow Sands, Salthouse direction	54° 5′ N. 3° 12′ W.	4.12.13	—	—	SN
LA 673	21	Barrow Channel	54° 4′ N. 3° 11′ W.	9.12.13	—	—	SN

Experiment III. 1913.

133 Plaice and 1 Sole. Liberated on the Edge of Blackpool Closed Ground, June 30th, 1913. Nos. LA 801-933.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 801	21	10 miles due W. of Blackpool, 14 fathoms	53° 45′ N. 3° 19′ W.	30.8.13	24	3	1T
LA 853	23	3 miles S.W. of Nelson Buoy, 8 fathoms	53° 40′ N. 3° 15′ W.	16.9.13	26	3	2T
LA 828	21	3 miles S.W. of Nelson Buoy	53° 40′ N. 3° 15′ W.	18.9.13	24·5	3½	2T
LA 909	18	10 miles N. of Liverpool Bar Lightship, 14 fathoms	53° 41′ N. 3° 17′ W.	18.9.13	20·5	2½	ST
LA 910	18	S. of Nelson Buoy	53° 42′ N. 3° 12′ W.	24.9.13	21·5	3½	2T
LA 877	18	3 miles S. of Morecambe Bay Lightship, 14 fathoms	53° 51′ N. 3° 29′ W.	2.10.13	21·5	3½	1T
LA 907	19	2 miles S. of Nelson Buoy, 7 fathoms	53° 40′ N. 3° 11′ W.	8.10.13	23	4	2T
LA 805	23	10 miles N. of Liverpool Bar Lightship, 13 fathoms	53° 41′ N. 3° 17′ W.	10.10.13	26	3	1T
LA 885	20	2 miles W.S.W. of Nelson Buoy	53° 41′ N. 3° 14′ W.	10.10.13	23·5	3½	2T
LA 893	24	2 miles S. of Nelson Buoy, 8 fathoms	53° 40′ N. 3° 11′ W.	13.10.13	28·5	4½	2T
LA 860	22	2 miles S.W. from Nelson Buoy, 8 fathoms	53° 41′ N. 3° 14′ W.	22.10.13	25	3	2T
LA 900	20	S.W. of Buoy in place of Bell Buoy, Old Ribble Channel, 3 fathoms	53° 41′ N. 3° 7′ W.	10.11.13	23·5	3½	2T
LA 847	20	New Channel, 2 miles from Lytham	53° 44′ N. 3° 2′ W.	25.11.13	—	—	—

S

Experiment III—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 928	20	Midway between Grange and Morecambe, Morecambe Bay	54° 8′ N. 2° 51′ W.	27.11.13	24·5	4½	SN
LA 827	17	Horse Bank, Southport	3° 39′ N 3° 6′ W.	28.11.13	21	4	2T
LA 843	20	N.W. Lightship, bearing N. by E., 14 fathoms	53° 33′ N. 3° 31′ W.	2.12.13	24·5	4½	ST
LA 912	18	5 miles N.N.W. from Great Ormes Head, 13 fathoms	53° 24′ N. 3° 58′ W	30.12.13	22·5	4½	1T

Experiment IV. 1913.

65 Plaice. Liberated 2 miles S.W. from Nelson Buoy, July 17th, 1913. Nos. LN 1-65.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 10	20	2 miles W.S.W. from Nelson Buoy	53° 41′ N. 3° 15′ W.	10.10.13	23	3	2T
LN 15	20	W. from Nelson Buoy, 11 fathoms	53° 42′ N. 3° 15′ W.	18.10.13	22	2	2T
LN 38	18·5	½ mile S.W. from Southport Pier	53° 39′ N. 3° 1′ W.	21.11.13	21	2½	2T

Experiment V. 1913.

283 Plaice and 14 Soles. Liberated near Nelson Buoy, September 17th, 1913. Nos. LN 101-386 (Plaice only).

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 299	21·5	3 miles S.W. from Nelson Buoy, 8 fathoms	53° 40′ N. 3° 15′ W.	16.9.13	21·5	0	2T
LN 342	20·5	2 miles W. from Nelson Buoy	53° 42′ N. 3° 16′ W.	18.9.13	20·5	0	2T
LN 150	22·5	10 miles N. from Liverpool Bar Lightship, 14 fathoms	53° 41′ N. 3° 17′ W.	18.9.13	22·5	0	ST
LN 364	24	2 miles W. from Nelson Buoy	53° 42′ N. 3° 16′ W.	18.9.13	24	0	2T
LN 365	22	W. from Nelson Buoy, 8 fathoms	53° 42′ N. 3° 15′ W.	19.9.13	22	0	2T
LN 179	25·5	2 miles S. from Nelson Buoy, 5 fathoms	53° 40′ N. 3° 11′ W.	25.9.13	—	—	2T
LN 367	21·5	2 miles S. from Nelson Buoy, 7 fathoms	53° 40′ N. 3° 14′ W.	30.9.13	22	½	2T
LN 329*	21	S.W. from Nelson Buoy	53° 42′ N. 3° 13′ W.	30.9.13	21·5	½	FS
LN 379	23	2 miles S.W. from Nelson Buoy, 7 fathoms	53° 41′ N. 3° 15′ W.	30.9.13	26	3	2T
LN 301	20	1 mile S.W. from Nelson Buoy	53° 41′ N. 3° 14′ W.	1.10.13	20	0	2T
LN 349	21	2 miles S.W. from Nelson Buoy	53° 42′ N. 3° 16′ W.	2.10.13	21	0	2T
LN 183	22·5	2 miles S. from Nelson Buoy, 7 fathoms	53° 40′ N. 3° 11′ W.	6.10.13	23	½	2T
LN 293	20	¼ mile outside Nelson Buoy	53° 42′ N. 3° 13′ W.	8.10.13	21	1	2T

* This fish was caught by the Fisheries Steamer "James Fletcher," and re-liberated the same day.

Experiment V—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 266	23	2 miles S. from Nelson Buoy, 7 fathoms	53° 40′ N. 3° 11′ W.	8.10.13	24	1	2T
LN 381	22	1 mile S.W. from Nelson Buoy, 8 fathoms	53° 41′ N. 3° 14′ W.	9.10.13	23·5	1½	2T
LN 212	23	S.W. from Nelson Buoy	53° 42′ N. 3° 13′ W.	9.10.13	23	0	2T
LN 315	22	2-3 miles W.S.W. from Nelson Buoy	53° 40′ N. 3° 17′ W.	9.10.13	24	2	2T
LN 376	21	3 miles S.W. from Nelson Buoy, 10 fathoms	53° 40′ N. 3° 15′ W.	9.10.13	23	2	2T
LN 372	22	2 miles W.S.W. from Nelson Buoy	53° 40′ N. 3° 17′ W.	10.10.13	22·5	½	2T
LN 186	24·5	5 miles W. from Nelson Buoy, 5 fathoms	53° 41′ N. 3° 21′ W.	10.10.13	—	—	2T
LN 107	22	10 miles N. from Liverpool Bar Lightship, 13 faths.	53° 41′ N. 3° 17′ W.	10.10.13	22	0	1T
LN 231	26·5	4 miles W. from Nelson Buoy, 12 fathoms	53° 41′ N. 3° 19′ W.	16.10.13	27	½	2T
LN 363	22·5	Nelson Buoy	53° 42′ N. 3° 14′ W.	24 10.13	22·5	0	2T
LN 103	21	2 miles S.W. from Nelson Buoy	53° 40′ N. 3° 14′ W.	24.10.13	21·5	½	2T
LN 176	23	,, ,,	,,	25.10.13	24	1	2T
LN 252	20	Nelson Buoy	53° 42′ N. 3° 14′ W.	25.10.13	20·5	½	2T
LN 346	22	Outside Nelson Buoy	53° 43′ N. 3° 13′ W.	25.10.13	22·5	½	2T
LN 359	22·5	2 miles S. from Nelson Buoy, 8 fathoms	53° 40′ N. 3° 11′ W.	28.10.13	22·5	0	2T

Experiment V—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 209	22	S.W. from Nelson Buoy	53° 42′ N. 3° 13′ W.	7.11.13	23·5	1½	2T
LN 151	21·5	Near Pinfold Buoy, Ribble Estuary	53° 42′ N. 3° 3′ W.	7.11.13	21·5	0	2T
LN 248	22	N.W. Buoy off Formby, 6 fathoms........	53° 33′ N. 3° 8′ W.	11.11.13	22·5	½	2T
LN 332	22	Near Buoy in place of Ansdell Buoy, River Ribble	53° 45′ N. 3° 4′ W.	25.11.13	23	1	2T
LN 214	24	———	—	27.11.13	—	—	—
LN 169	22	———	—	1.12.13	24	2	—
LN 192	23	———	—	1.12.13	25	2	—
LN 287	22·5	Eastham Channel	53° 18′ N. 2° 51′ W.	1.12.13	23·5	1	2T
LN 258	24	5 miles W. from Great Ormes Head, 11 fathoms ...	53° 19′ N. 4° 1′ W.	1.12.13	25·5	1½	1T
LN 185	20·5	,, ,, ,, ,,	,,	1.12.13	22·5	2	1T
LN 383	23	Great Ormes Head, bearing S.E., 15 fathoms	53° 24′ N. 4° 3′ W.	2.12.13	23	0	ST
LN 155	20·5	Near Silverdale, Morecambe Bay	54° 11′ N. 2° 51′ W.	3.12.13	22·5	2	SN
LN 323	20	Horse Bank, Southport	53° 39′ N. 3° 6′ W.	5.12.13	20	0	2T
LN 360	24	Point Lynus, bearing N.W. by W., 10 fathoms	53° 23′ N. 4° 5′ W.	7.12.13	24	0	1T

Experiment V—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 358	24	Between Rock Ferry and Eastham, 5 fathoms	53° 20′ N. 2° 56′ W.	12.12.13	24	0	2T
LN 356	22	Old Preston Channel	53° 43′ N. 2° 56′ W.	13.12.13	—	—	2T
LN 199	21	Near Lytham Pier	53° 44′ N. 3° 1′ W.	15.12.13	22·5	$1\frac{1}{2}$	—
LN 188	20	Outside Greenfield, Holywell	53° 18′ N. 3° 11′ W.	15.12.13	—	—	SN
LN 312	26	Opposite Morecambe	54° 5′ N. 2° 50′ W.	17.12.13	28	2	SN
LN 315	23	Near Eastham, 4 fathoms	53° 19′ N. 2° 52′ W.	17.12.13	—	—	2T
LN 244	24	Great Ormes Head, bearing S.S.E., 8 miles distant, 17 fathoms.	53° 26′ N. 4° 1′ W.	17 12.13	26	2	1T
LN 173	25	Gut Channel, Ribble Estuary	53° 43′ N. 3° 2′ W.	20.12.13	26·5	$1\frac{1}{2}$	2T
LN 326	21	4 miles, bearing N.W. from Constable Buoy, 20 fathoms.	53° 29′ N. 3° 54′ W.	20.12.13	—	—	1T
LN 161	21	Old Preston Channel	53° 43′ N. 2° 56′ W.	22.12.13	23·5	$2\frac{1}{2}$	2T
LN 272	22	Grange Channel	54° 10′ N. 2° 55′ W.	23.12.13	22·5	$\frac{1}{2}$	2T
LN 211	21	5 miles E.N.E. from Great Ormes Head, 13 fathoms	53° 25′ N. 3° 44′ W.	26.12.13	21·5	$\frac{1}{2}$	1T
LN 164	21	Bog Hole, Southport	53° 38′ N. 3° 4′ W.	30.12.13	22·5	$1\frac{1}{2}$	2T
L 23	24	3 miles S.W. from Nelson Buoy, 8 fathoms	53° 40′ N. 3° 15′ W.	16.9.13	24	0	2T

Experiment VI. 1913.

167 Plaice. Liberated in Beaumaris Bay, November 20th, 1913. Nos. LN 401-567.
53 Plaice. Liberated in Llandudno Bay, November 20th, 1913. Nos. LN 568-620.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 554	20	Red Wharf Bay, 16 fathoms	53° 19′ N. 4° 10′ W.	21.11.13	20·5	½	1T
LN 555	19·5	3 miles S.W. from Puffin Island, 14 fathoms	53° 17′ N. 4° 3′ W.	21.11.13	19·5	0	1T
LN 563	19·5	8 miles N. from Great Ormes Head, 15 fathoms	53° 28′ N. 3° 56′ W.	23.11.13	19·5	0	1T
LN 586	22·5	Conway Bay, 7 fathoms	53° 18′ N. 3° 53′ W.	24.11.13	22·5	0	1T
LN 561	18·5	,, ,,	,,	24.11.13	18·5	0	1T
LN 612	22·5	Great Ormes Head, bearing W., 9 fathoms	53° 20′ N. 4° 00′ W.	27.11.13	22·5	0	1T
LN 584	24·5	3 miles W. from Great Ormes Head	53° 20′ N. 3° 57′ W.	29.11.13	24·5	0	1T
LN 459	23	Conway Bay, 14 fathoms	53° 24′ N. 3° 54′ W.	30.11.13	23	0	1T
LN 487	22	5 miles N. from Great Ormes Head, 16 fathoms	53° 25′ N. 3° 55′ W.	30.11.13	22·5	½	1T
LN 473	24·5	W.S.W. from Great Ormes Head, 11 fathoms	53° 18′ N. 3° 57′ W.	30.11.13	25	½	1T
LN 433	22·5	,, ,,	,,	30.11.13	23	½	1T
LN 601	19·5	4 miles W. from Great Ormes Head	53° 19′ N. 3° 59′ W.	30.11.13	19·5	0	1T

Experiment VI—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 409	31	Great Ormes Head, bearing 5 miles S.S.W.	53° 25′ N. 3° 53′ W.	30.11.13	31	0	1T
LN 403	24	3 miles N.W. from Great Ormes Head	53° 22′ N. 3° 57′ W.	4.12.13	24	0	1T
LN 521	24·5	5 miles E.N.E. from Great Ormes Head, 15 fathoms	53° 24′ N. 3° 46′ W.	6.12.13	25	½	1T
LN 533	24·5	,, ,, ,,	,,	6.12.13	24·5	0	1T
LN 437	24	2 miles N. from Puffin Island	53° 21′ N. 4° 4′ W.	8.12.13	24	0	1T
LN 468	26·5	3 miles W.N.W. from Great Ormes Head	53° 21′ N. 3° 57′ W.	8.12.13	26·5	0	1T
LN 506	24	Off Great Ormes Head	53° 21′ N. 3° 53′ W.	8.12.13	24	0	ST
LN 545	29·5	Point Lynus, bearing N.W. by W., 10 fathoms	53° 27′ N. 4° 22′ W.	9.12.13	29·5	0	1T
LN 435	23	Conway Bay, 10 fathoms	53° 23′ N. 3° 58′ W.	10.12.13	23	0	1T
LN 620	23	Conway Bay	53° 19′ N. 3° 59′ W.	10.12.13	23	0	1T
LN 415	25	5 miles N.N.E. from Great Ormes Head, 16 fathoms	53° 26′ N. 3° 52′ W.	10.12.13	25	0	1T
LN 511	21·5	Great Ormes Head, 5 fathoms	53° 21′ N. 3° 54′ W.	10.12.13	21·5	0	1T
LN 523	29·5	Half-way between Great Ormes Head and Puffin Island	53° 20′ N. 3° 57′ W.	10.12.13	29·5	0	IT
LN 483	24·5	Conway Bay, 14 fathoms	53° 24′ N. 3° 57′ W.	10.12.13	24·5	0	1T
LN 464	22	3 miles from Puffin Island, bearing N.W., 7 fathoms	53° 20′ N. 4° 6′ W.	11.12.13	22	0	1T

Experiment VI—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 540	19	N.E. by E. from Great Ormes Head, 10 fathoms	53° 24′ N. 3° 48′ W.	12.12.13	19	0	1T
LN 513	24·5	Conway Bay	53° 22′ N. 3° 59′ W.	12.12.13	24·5	0	1T
LN 416	24	,,	,,	12.12.13	24	0	1T
LN 453	24·5	,,	,,	12.12.13	24·5	0	1T
LN 525	25	Off Great Ormes Head, 9 fathoms	53° 23′ N. 3° 54′ W.	12.12.13	25·5	½	1T
LN 474	31·5	Off Conway Bay, 12 fathoms	53° 24′ N. 3° 59′ W.	13.12.13	31·5	0	1T
LN 572	26	,, ,,	,,	13.12.13	26	0	1T
LN 551	22·5	,, ,,	,,	13.12.13	22·5	0	1T
LN 575	24	Off Conway Bay, 10 fathoms	53° 23′ N. 3° 58′ W.	13.12.13	24	0	1T
LN 573	21·5	,, ,,	,,	14.12.13	21·5	0	1T
LN 518	23·5	Off Conway Bay, 12 fathoms	53° 24′ N. 3° 59′ W.	14.12.13	23·5	0	1T
LN 605	23	Off Conway Bay, 14 fathoms	53° 25′ N. 3° 40′ W.	14.12.13	23	0	1T
LN 529	22	,, ,,	,,	14.12.13	22·5	½	IT
LN 567	19	Off Conway Bay, 12 fathoms	53° 24′ N. 3° 59′ W.	14.12.13	19	0	1T
LN 481	22	Great Ormes Head, 16 fathoms	53° 25′ N. 3° 55′ W.	14.12.13	22	0	1T

Experiment VI—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LN 449	25·5	Conway Bay, 8 fathoms	53° 22′ N. 3° 56′ W.	14.12.13	26	½	1T
LN 579	23	,, ,,	,,	14.12.13	23	0	1T
LN 446	24	3 miles from Great Ormes Head, 10 fathoms	53° 23′ N. 3° 51′ W.	14.12.13	24	0	1T
LN 414	31	15 miles from Great Ormes Head, bearing W.S.W., 13 fathoms	53° 30′ N. 3° 33′ W.	16.12.13	31	0	1T
LN 478	37	Conway Bay, 7 fathoms	53° 22′ N. 3° 57′ W.	17.12.13	37	0	1T
LN 617	21	Conway Bay, 5 fathoms	53° 21′ N. 3° 57′ W.	17.12.13	—	—	1T
LN 618	20	,, ,,	,,	17.12.13	—	—	1T
LN 472	23·5	Conway Bay, bearing N.W., 12 fathoms	53° 24′ N. 4° 8′ W.	18.12.13	24	½	1T
LN 484	21	Conway Bay, 7 fathoms	53° 22′ N. 3° 57′ W.	22.12.13	21	0	1T
LN 524	24·5	,, ,,	,,	22.12.13	24·5	0	1T
LN 471	22	3 miles N.E. from Constable Buoy, 14 fathoms	53° 26′ N. 3° 31′ W.	23.12.13	22	0	IT
LN 441	21	5 miles E.N.E. from Great Ormes Head, 13 fathoms	53° 24′ N. 3° 45′ W.	24.12.13	21	0	1T
LN 490	29	6 miles E.N.E. from Great Ormes Head, 13 fathoms	53° 25′ N. 3° 44′ W.	24.12.13	29·5	½	1T
LN 431	22	5 miles E.N.E. from Great Ormes Head, 13 fathoms	53° 24′ N. 3° 45′ W.	26.12.13	22·5	½	1T
LN 494	27	10 miles W.N.W. from Great Ormes Head, 16 fathoms	53° 27′ N. 4° 15′ W.	27.12.13	27	0	1T

Experiment I. 1912.

212 Plaice. Liberated near Nelson Buoy, June 5th, 1912.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 233	21·5	11 miles S.E. from Bahama Ship	54° 15′ N. 3° 56′ W.	1.6.13	31	9½	ST
LA 267	27·5	1 mile S. from Nelson Buoy, 7 fathoms	53° 41′ N. 3° 12′ W.	24.9.13	35	7½	2T
LA 200	23	Mouth of Loch Ryan	55° 0′ N. 5° 5′ W.	10.10.13	30	7	GN

Experiment II. 1912.

153 Plaice. Liberated near Nelson Buoy, October 3rd, 1912.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 439	19·5	Magazine Bank, New Brighton, 3 fathoms	53° 27′ N. 3° 4′ W.	26.2.13	19·5	0	2T
LA 381	22·5	2 miles W. from St. Annes Pier	53° 45′ N. 3° 7′ W.	26.2.13	22·5	0	2T
LA 359	23	West End of Rock Channel, 3 fathoms	53° 25′ N. 3° 12′ W.	6.3.13	—	—	2T
LA 410	22·5	—	—	?.3.13	23	½	—

Experiment II—*Continued.*

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 325	21	Entrance of Ribble, 4 fathoms	53° 43′ N. 3° 9′ W.	22.4.13	21	0	2T
LA 389	21	Bog Hole, Southport, 2 fathoms	53° 38′ N. 3° 4′ W.	30.4.13	—	—	2T
LA 349	24	12 miles N.N.W. from St. Bees Head	54° 40′ N. 3° 52′ W.	1.6.13	26	2	ST
LA 347	21	Liverpool Bar Lightship, 14 fathoms	53° 32′ N. 3° 18′ W.	18.6.13	24·5	3½	1T
LA 407	28	5 miles S. from Morecambe Bay Lightship	53° 49′ N. 3° 28′ W.	2.8.13	30	2	1T
LA 310	24·5	10 miles S.W. from Morecambe Bay Lightship	53° 45′ N. 3° 38′ W.	7.8.13	28	3½	2T
LA 447	23·5	10 miles S. from Coningbeg Lightship, 35 fathoms	51° 52′ N. 6° 40′ W.	7.8.13	28·5	5	ST.
LA 330*	20·5	Near Nelson Buoy	53° 43′ N. 3° 13′ W.	16.7.13	34·5	14	FS
LA 419	22	4-5 miles N.N.W. from Nelson Buoy, 11 fathoms	53° 46′ N. 3° 17′ W.	10.10.13	30	8	1T
LA 418	23·5	2 miles S.W. from Nelson Buoy, 8 fathoms	53° 40′ N. 3° 14′ W.	22.10.13	31	7½	2T
LA 444	21·5	2 miles S.W. from Nelson Buoy	53° 40′ N. 3° 14′ W.	25.10.13	27	5½	2T
LA 380	22	10 miles from Bahama Lightship S. by E., 12 fathoms	54° 11′ N. 4° 4′ W.	10.12.13	28	6	ST

* This fish was captured by the Fishery Steamer "James Fletcher," and re-liberated the same date.

Experiment III. 1912.

45 Plaice. Liberated in Luce Bay, October 22nd, 1912.

No. of Label.	Length when Liberated in cms.	Place of Capture.	Latitude and Longitude.	Date of Recapture.	Length when Recaptured in cms.	Increase in Length in cms.	Method of Recapture.
LA 476	28	About 3 miles N. from Drummore, Luce Bay, 5 fathoms	54° 44′ N. 4° 54′ W.	8.3.13	29	1	GN
LA 490	20·5	Luce Bay	54° 49′ N. 4° 50′ W.	14.3.13	20·5	0	GN
LA 491	24·5	3 miles from Sandhead, Luce Bay, 4 fathoms	54° 46′ N. 4° 52′ W.	17.7.13	30·5	6	GN
LA 463	24	3 miles S.W. from Stairhaven Harbour, Luce Bay...	54° 47′ N. 4° 49′ W.	29.7.13	30·5	6½	GN
LA 464	33·5	3 miles E. from Sandhead Village, Flounder net, 6 feet of water	54° 47′ N. 4° 52′ W.	15.8.13	38·5	5	FN

REPORT ON HYDROGRAPHIC OBSERVATIONS MADE IN THE IRISH SEA DURING 1913, WITH A NOTE ON THE POSITION OF THE ISOTHERMS IN THE NORTH ATLANTIC DURING 1907-1913.

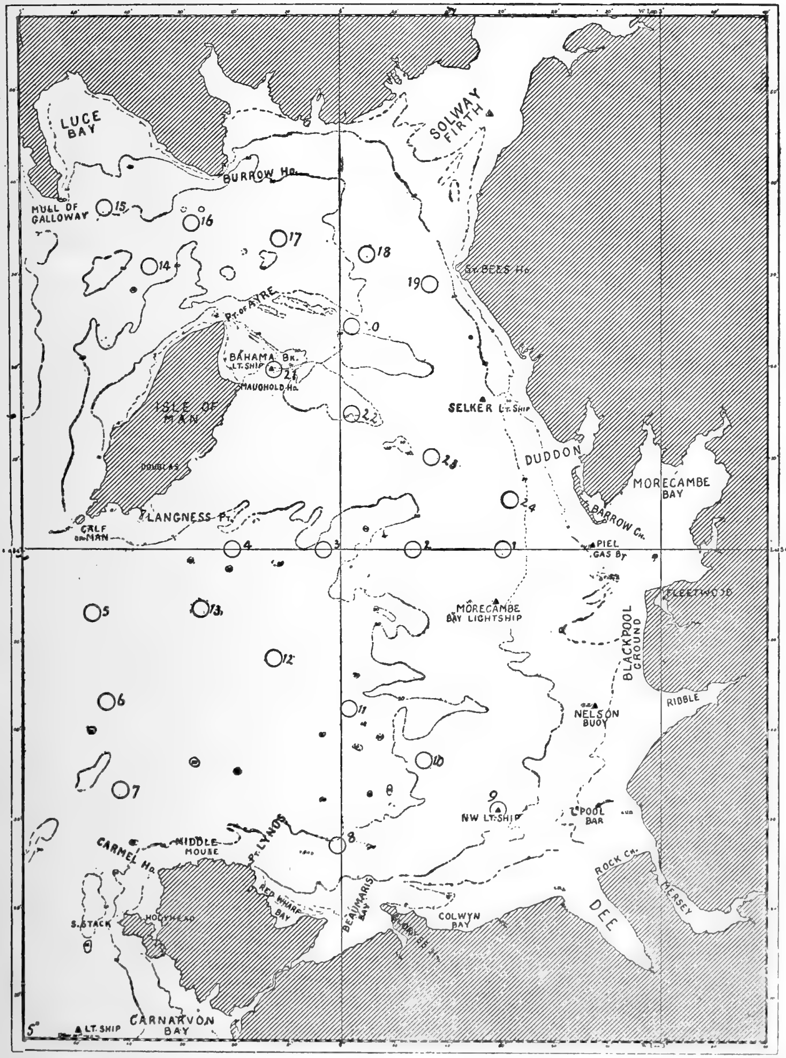
By Henry Bassett, Jun., D.Sc.,
Professor of Chemistry, University College, Reading.

(With three Charts.)

During the past year hydrographic observations have been made at the 24 Stations, the positions of which are indicated on the chart on page 191. Monthly observations have been made at Stations 1 to 7, which are regarded as the most important, while observations at the remaining Stations have only been made on the "quarterly" cruises in February, May, August, and November. Bottom, intermediate, and surface observations were made at Stations 5, 6, and 7; elsewhere only surface observations were made. The weather during the cruises has been invariably bad, and on one or two occasions several Stations have had to be omitted.

The salinities at the several Stations during 1913 show some noteworthy features. In the first place the water samples obtained from the three deep Stations (5, 6, and 7) have been remarkably similar to those obtained in 1912. Not only were the salinities unusually high at these Stations in both years, but the actual monthly values were, in most cases, nearly identical. The temperatures at these three stations have shown rather greater differences, having been somewhat lower during the summer months of 1913, but otherwise higher than during the corresponding months of 1912.

When we consider the Stations in the shallower water to the North of the line, Calf of Man-Holyhead, we find a



Observation Stations in 1913.

rather different state of affairs. In the great majority of cases the water was considerably salter during 1913 than during 1912, while at the same time there was generally a greater difference between the maximum and minimum salinity at any one Station.

The water in our area of the Irish Sea was found to be astonishingly uniform and of relatively high salinity during the November* cruise of 1913. The salinity at all the Stations (with the two exceptions of Stations 1 and 24) was found to be over 34 $^{\circ}/_{\circ\circ}$—at 18 Stations being 34·2 $^{\circ}/_{\circ\circ}$ or over.

On the whole it would seem that the "Drift" through our area in 1913 (and the salinity changes thereby produced) bore more resemblance to that of 1912 than of any other year since we started observations in 1906. That this would probably be the case was foreseen in last year's report. It was also suggested that, in view of the close connection which appeared to exist between the hydrographic conditions in the Irish Sea and the weather, we should experience another bad summer in 1913, similar to that of 1912. This expectation was not fulfilled, for the summer months were unusually dry, instead of wet. At the same time, however, it was not what many people consider very fine weather owing to its coolness and lack of sunshine. The prevalence of northerly and easterly winds was remarkable.

It is possible that this lack of agreement between anticipation and result may indicate the complete breakdown of the connection between hydrographic conditions in the Irish Sea and the weather which I have tried to trace during the past six years. I am loth to believe this, however, and think it more probable that there is some further factor which is not yet understood. What this

* Actually October 27—November 1.

may be, time will have to show. Certain it is that there was something peculiar about the conditions in the Irish Sea during 1913, for although the salinities gave no indications of any southward flow of the water, yet, of a number of carefully-weighted drift bottles liberated between Dublin and Holyhead in June, a certain proportion was washed up on the shores of Cardigan Bay, and the East coast of Ireland in August, September, and October. It seems possible to explain this by supposing that the north-easterly winds then prevailing had transferred merely a thin surface layer of water to the South (and with it the bottles), while the main body of water was all the time slowly travelling northward. The number of bottles found is, however, rather too small to allow us to make any really trustworthy deductions from this experiment. As regards the salinity changes in progress at the time of writing, I will merely state that it looks as though the maximum salinity (34·40 ‰ at Station 6) for the present season has already been passed in December last. This is what happened before the magnificent summer of 1911.

January 7 to 8, 1913.

Stations I. to IV., 7/1/13. Surface observations only.

Station.		Time.	T°	Cl‰	S‰	σ_t
I.	54°N.; 3°30′W.	12.50 p.m.	7·2	18·27	33·01	25·84
II.	54°N.; 3°47′W.	1.50 p.m.	7·8	18·71	33·82	26·30
III.	54°N.; 4°4′W.	3.30 p.m.	8·6	18·98	34·29	26·64
IV.	54°N.; 4°20′W.	4.55 p.m.	8·7	19·00	34·33	26·66

Station V., 53° 53′ N.; 4° 46′ W. 8/1/13 (10.45 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	9·05	18·98	34·29	26·57
30	9·0	18·96	34·25	26·55
68	9·0	18·96	34·25	26·55

Station VI., 53° 43′ N.; 4°44′ W. 8/1/13 (12 noon).

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	9·1	19·03	34·38	26·64
30	9·1	19·02	34·36	26·62
70	9·05	19·02	34·36	26·63

Station VII., 53° 33′ N.; 4°41′ W. 8/1/13 (1.15 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	8·8	18·99	34·31	26·63
30	8·8	18·99	34·31	26·63
63	8·8	18·99	34·31	26·63

February 4 to 8, 1913.

Stations I. to XXIVA. Surface observations only. Owing to the very bad weather experienced during this cruise, only surface samples could be collected at Stations V., VI., and VII., while Stations XV. and XVI. were omitted altogether Stations XXIIA., XXIIIA., and XXIVA. were on a line from Maughold Head to Piel Gas Buoy, and thus do not quite coincide with Stations XXII., XXIII., and XXIV.

Station.		Date and Time.		T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	4.2.13	a.m. 9.45	5·4	18·08	32·66	25·80
II.	54°N. ; 3°47′W.	4.2.13	10.50	6·6	18·79	33·96	26·68
III.	54°N. ; 4°4′W.	4.2.13	p.m. 1.20	7·4	18·97	34·31	26·84
IV.	54°N. ; 4°20′W.	4.2.13	2.40	7·7	19·02	34·36	26·84
V.	53°53′N. ; 4°46′W.	5.2.13	a.m. 9.0	8·0	19·11	34·52	26·92
VI.	53°43′N. ; 4°44′W.	5.2.13	10.15	8·2	19·13	34·56	26·92
VII.	53°33′N. ; 4°41′W.	5.2.13	11.20	7·5	18·91	34·16	26·71
VIII.	53°27′N. ; 4°5′W.	5.2.13	p.m. 1.40	7·4	18·92	34·18	26·74
IX.	53°31′N. ; 3°31′W.	6.2.13	a.m. 8.15	7·1	18·93	34·20	26·79
X.	53°37′N. ; 3°45′W.	6.2.13	9.15	7·2	18·98	34·29	26·85
XI.	53°43′N. ; 3°58′W.	6.2.13	10.10	7·5	19·01	34·34	26·84
XII.	53°48′N. ; 4°12′W.	6.2.13	11.5	7·8	19·05	34·45	26·89
XIII.	53°54′N. ; 4°27′W.	6.2.13	noon 12.0	7·9	19·03	34·38	26·82
XIV.	54°32′N. ; 4°37′W.	7.2.13	p.m. 1.30	7 9	19·00	34·33	26·78
XVII.	54°34′N. ; 4°12′W.	7.2.13	12.5	6·2	18·45	33·33	26·23
XVIII.	54°32′N. ; 3°55′W.	7.2.13	a.m. 11.5	5 8	18·25	32·97	26·00
XIX.	54°29′N. ; 3°43′W.	7.2.13	10.5	5·3	18·05	32·61	25·77
XX.	54°24′N. ; 3°57′W.	7.2.13	9.10	5·7	18·27	33·01	26·04
XXI.	54°20′N. ; 4°13′W.	7.2.13	8.10	6·9	18·86	34·07	26·72
XXIIA.	54°14′N. ; 4°W.	8.2.13	a.m. 7.45	7·3	19·01	34·34	26 88
XXIIIA.	54°9′N. ; 3°43′W.	8.2.13	8.45	6·7	18·86	34·07	26·75
XXIVA.	54°5′N. ; 3°28′W.	8.2.13	9.40	4·9	17·23	31·13	24·65

March 4 to 5 1913.

Stations I. to IV., 4/3/13. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	11.5 a.m.	5·5	18·02	32·56	25·71
II.	54°N. ; 3°47′W.	12.15 p.m.	6·6	18·82	34·00	26·71
III.	54°N. ; 4°4′W.	1.15 p.m.	6·9	18·95	34·23	26·85
IV.	54°N. ; 4°20′W.	2.10 p.m.	7·6	19·01	34·34	26·84

Station V., 53° 53′ N. ; 4° 46′ W. 5/3/13 (10.50 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	7·6	19·13	34·56	27·01
30	7·55	19·10	34·51	26·97
56	7·6	19·10	34·51	26·97

Station VI., 53° 43′ N. ; 4° 44′ W. 5/3/13 (12 noon.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	7·5	19·07	34·45	26·93
30	7·5	19·07	34·45	26·93
64	7·5	19·06	34·43	26·92

Station VII., 53° 33′ N. ; 4° 41′ W. 5/3/13 (1.10 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	7·4	19·07	34·45	26·95
30	7·4	19·06	34·43	26·94
54	7·4	19·08	34·47	26·97

April 2, 1913.

Stations I. to IV. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	10.0 a.m.	6·4	18·48	33·39	26·25
II.	54°N. ; 3°47′W.	10.55 a.m.	6·5	18·78	33·93	26·66
III.	54°N. ; 4°4′W.	11.50 a.m.	6·9	18·99	34·31	26·91
IV.	54°N. ; 4°20′W.	12.45 p.m.	7·2	18·98	34·29	26·85

Station V., 53° 53′ N.; 4° 46′ W. 2/4/13 (2.5 p.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	7·5	19·07	34·45	26·93
30	7·3	19·07	34·45	26·96
77	7·25	19·07	34·45	26·97

Station VI., 53° 43′ N.; 4° 44′ W. 2/4/13 (3.15 p.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	7·5	19·09	34·49	26·96
30	7·3	19·09	34·49	26·99
58	7·3	19·11	34·52	27·02

Station VII., 53° 33′ N.; 4° 41′ W. 2/4/13 (4.30 p.m.)

Depth (metres)	T°	Cl°/₀₀	S°/₀₀	σ_t
0	7·4	19·08	34·47	26·97
30	7·3	19·11	34·52	27·02
66	7·3	19·17	34·63	27·10

May 5 to 8, 1913.

Stations I. to IV., 5/5/13. Surface observations only.

Station.		Time.	T°	Cl°/₀₀	S°/₀₀	σ_t
I.	54°N.; 3°30′W.	12.45 p.m.	9·1	18·14	32·77	25·38
II.	54°N.; 3°47′W.	1.45 p.m.	9·2	18·83	34·02	26·34
III.	54°N.; 4°4′W.	4.50 p.m.	9·4	18·95	34·23	26·47
IV.	54°N.; 4°20′W.	6.5 p.m.	8·2	19·05	34·42	26·80

Station V., 53° 53′ N.; 4° 46′ W. 6/5/13 (8.15 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	8·2	19·06	34·43	26·82
30	8·1	19·07	34·45	26·85
60	8·2	19·07	34·45	26·83

Station VI , 53° 43′ N. ; 4° 44′ W. 6/5/13 (9.25 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	8·35	19·11	34·52	26·87
30	8·3	19·12	34·54	26·89
66	8·3	19·12	34·54	26·89

Station VII., 53° 33′ N. ; 4° 41′ W. 6/5/13 (10.35 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	8·5	19·06	34·43	26·77
30	8·4	19·05	34·42	26·77
56	8·4	19·06	34·43	26·79

Stations VIII. to XXIV. Surface observations only.

Station.		Date and Time.		T°	Cl°/oo	S°/oo	σ_t
VIII	53°27′N. ; 4°5′W.	6.5.13	1.30 p.m.	8·0	19·00	34·33	26·76
IX.	53°31′N. ; 3°31′W.	6.5.13	3.50	8·2	18·76	33·89	26·39
X.	53°37′N. ; 3°45′W.	6.5.13	4.50	7·8	18·94	34·22	26·70
XI.	53°43′N. ; 3°58′W.	6.5.13	5.50	7·9	19·03	34·38	26·83
XII.	53°48′N. ; 4°12.W.	6.5.13	6.55	8·0	19·07	34·45	26·86
XIII.	53°54′N. ; 4°27′W.	6.5.13	8.0 p.m.	8·0	19·10	34·51	26·91
XIV.	54°32′N. ; 4°37′W.	7.5.13	4.0	8·4	19·00	34·33	26·70
XV.	54°37′N. ; 4°45′W.	7.5.13	3.0	8·1	18·70	33·78	26·33
XVI.	54°35′N. ; 4°27′W.	7.5.13	2,15	8·1	18·58	33·57	26·15
XVII.	54°34′N. ; 4°12′W.	7.5.13	1.25	8·0	18·57	33·55	26·16
XVIII.	54°32′N. ; 3°55′W.	7.5.13	12.30 a.m.	8·0	18·66	33·71	26·29
XIX.	54°29′N. ; 3°43′W.	7.5.13	11.15	8·4	18·27	33·01	25·67
XX.	54°24′N. ; 3°57′W.	7.5.13	8.50	7·7	18·51	33·44	26·12
XXI.	54°20′N. ; 4°13′W.	7.5.13	7.50	8·2	18·85	34·05	26·52
XXII.	54°15′N. ; 3°57 W.	8.5.13	11.35 p.m.	8·2	18·57	33·55	26·13
XXIII.	54°10′N. ; 3°42′W.	8.5.13	1.0	8·0	18·60	33·60	26·20
XXIV	54°5′N. ; 3°27′W.	8.5.13	2.15	8·0	18·39	33·22	25·91

June 2 to 3, 1913.

Stations I. to IV., 2/6/13. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N.; 3°30′W.	12.45 p.m.	11·8	18·25	32·97	25·07
II.	54°N.; 3°47′W.	3.40 p.m.	10·6	18·64	33·68	25·84
III.	54°N.; 4°4′W.	4.40 p.m.	10·0	18·97	34·27	26·41
IV.	54°N.; 4°20′W.	5.40 p.m.	9·9	19·13	34·56	26·64

Station V., 53° 53′ N.; 4° 46′ W. 3/6/13 (9.55 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·25	19·10	34·51	26·54
30	9·85	19·11	34·52	26·62
74	9·75	19·10	34·51	26·61

Station VI., 53° 43′ N.; 4° 44′ W. 3/6/13 (11.5 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·25	19·07	34·45	26·50
30	9·9	19·06	34·43	26·55
70	9·95	19·07	34·45	26·54

Station VII., 53° 33′ N.; 4° 41′ W. 3/6/13 (12.10 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	10·8	19·01	34·34	26·32
30	10·3	19·01	34·34	26·41
62	10·4	19·02	34·36	26·40

July 1, 1913.

Stations I. to IV. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	9.5 a.m.	13·65	18·39	33·22	24·90
II.	54°N. ; 3°47′W.	10.0 a.m.	14·3	18·39	33·22	24·77
III.	54°N. ; 4°4′W.	10.55 a.m.	14·2	18·63	33·66	25·12
IV.	54°N. 4°20′W.	11.55 a.m.	13·6	18·94	34·22	25·68

Station V., 53° 53′ N. ; 4° 46′ W. 2.45 p.m.

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	12·1	19·00	34·33	26·06
30	11·63	19·02	34·36	26·18
64	11·43	19·03	34·38	26·24

Station VI., 53° 43′ N. ; 4° 44′ W. 4 p.m.

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	11·9	19·04	34·40	26·16
30	11·38	19·03	34·38	26·24
63	11·38	19·02	34·36	26·22

Station VII., 53° 33′ N. ; 4° 41′ W. 5 p.m.

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	12·2	19·00	34·33	26·05
30	11·75	19·00	34·33	26·13
60	11·8	19·01	34·34	26·14

July 28 to 31, 1913.

Stations I. to IV., 28/7/13. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	12.50 p.m.	15·4	18·57	33·55	24·79
II.	54°N. ; 3°47′W.	3.5 p.m.	15·4	18·65	33·69	24·90
III.	54°N. ; 4°4′W.	4.5 p.m.	15·7	18·70	33·78	24·91
IV.	54°N. ; 4°20′W.	5.10 p.m.	16·4	18·88	34·11	25·00

Station V., 53° 53′ N. ; 4° 46′ W. 29/7/13 (8.40 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	12·75	19·04	34·40	26·00
30	12·35	19·04	34·40	26·08
92	11·95	19·04	34·40	26·14

Station VI., 53° 43′ N. ; 4° 44′ W. 29/7/13 (9.45 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	12·9	19·04	34·40	25·97
30	12·6	19·04	34·40	26·03
60	12·6	19·04	34·40	26·03

Station VII., 53° 33′ N. ; 4° 41′ W. 29/7/13 (10.50 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·7	19·03	34·38	25·79
30	13·3	19·03	34·38	25·87
63	13·3	19·03	34·38	25·87

Stations VIII. to XXIV. Surface observations only.

Station.		Date and Time.		T°	Cl°/oo	S°/oo	σ_t
			p.m.				
VIII.	53°27′N. ; 4°5′W.	29.7.13	1.25	15·0	18·85	34·05	25·26
IX.	53°31′N. ; 3°31′W.	29.7.13	3.15	16·8	18·32	33·10	24·12
X.	53°37′N. ; 3°45′W.	29.7.13	4.15	16·6	18·51	33·44	24·43
XI.	53°43′N. ; 3°58′W.	29.7.13	5.15	16·4	18·64	33·68	24·66
XII.	53°48′N. ; 4°12′W.	29.7.13	6.10	14·0	19·01	34·34	25·70
XIII.	53°54′N. ; 4°27′W.	29.7.13	7.10	14·6	19·02	34·36	25·58
XIV.	54°32′N. ; 4°37′W.	30.7.13	3.50	13·9	18·94	34·22	25·62
XV.	54°37′N. ; 4°45′W.	30.7.13	3.5	14·3	18·92	34·18	25·51
XVI.	54°35′N. ; 4°27′W.	30.7.13	2.15	14·2	18·87	34·09	25·46
XVII.	54°34′N. ; 4°12′W.	30.7.13	1.25	15·6	18·87	34·09	25·16
XVIII.	54°32′N. ; 3°55′W.	30.7.13	12.30	16·2	18·62	33·64	24·68
			a.m.				
XIX.	54°29′N. ; 3°43′W.	30.7.13	10.0	16·2	18·62	33·64	24·68
XX.	54°24′N. ; 3°57′W.	30.7.13	9.0	15·7	18·68	33·75	24·86
XXI.	54°20′N. ; 4°13′W.	30.7.13	8.0	14·2	18·88	34·11	25·48
XXII.	54°15′N. ; 3°57′W.	31.7.13	5.30	15·4	18·70	33·78	24·97
XXIII.	54°10′N. ; 3°42′W.	31.7.13	6.25	15·1	18·77	33·91	25·16
XXIV.	54°5′N. ; 3°27′W.	31.7.13	7.25	15·3	18·61	33·62	24·87

September 8 to 9, 1913.

Stations I. to IV., 8/9/13. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	4.35 p.m.	15·4	18·78	33·93	25·07
II.	54°N. ; 3°47′W.	6.40 p.m.	15·1	18·82	34·00	25·20
III.	54°N. ; 4°4′W.	7.40 p.m.	15·0	18·87	34·09	25·29
IV.	54°N. ; 4°20′W.	8.40 p.m.	14·5	18·97	34·27	25·54

Station V., 53° 53′ N. ; 4° 46′ W. 9/9/13 (9.35 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·8	18·99	34·31	25·72
30	13·45	19·00	34·33	25·80
67	13·5	19·00	34·33	25·79

Station VI., 53° 43′ N.; 4° 44′ W. 9/9/13 (10.45 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·65	19·01	34·34	25·77
30	13·4	19·00	34·33	25·81
69	13·5	19·00	34·33	25·79

Station VII., 53° 33′ N.; 4° 41′ W. 9/9/13 (12 noon).

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	14·2	18·99	34·31	25·63
30	13·7	19·01	34·34	25·76
96	13·95	19·01	34·34	25·71

October 7 to 8, 1913.

Stations I. to IV., 7/10/13. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N.; 3°30′W.	8.5 a.m.	14·2	18·86	34·07	25·45
II.	54°N.; 3°47′W.	9.10 a.m.	14·2	18·88	34·11	25·48
III.	54°N.; 4°4′W.	10.15 a.m.	13·65	18·98	34·29	25·73
IV.	54°N.; 4°20′W.	11.20 a.m.	13·5	18·98	34·29	25·76

Station V., 53° 53′ N.; 4° 46′ W. 8/10/13 (8.30 a.m.)

Depth metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·5	18·96	34·25	25·73
30	13·3	18·96	34·25	25·77
80	13·4	18·95	34·23	25·74

Station VI., 53° 43′ N. ; 4° 44′ W. 8/10/13 (9.40 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·6	18·98	34·29	25·74
30	13·5	18·98	34·29	25·76
55	13·6	18·98	34·29	25·74

Station VII., 53° 33′ N. ; 4° 41′ W. 8/10/13 (10.50 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	14·25	18·94	34·22	25·54
30	14·1	18·94	34·22	25·57
57	14·2	18·94	34·22	25·55

October 27 to November 1, 1913.

Stations I. to IV., 27/10/13. Surface observations only.

Station.		Time.	T°	Cl°/oo	S°/oo	σ_t
I.	54°N. ; 3°30′W.	12.45 p.m.	12·2	18·63	33·66	25·53
II.	54°N. ; 3°47′W.	1.50 p.m.	12·9	18·89	34·13	25·75
III.	54°N. ; 4°4′W.	4.5 p.m.	13·0	18·97	34·27	25·85
IV.	54°N. ; 4°20′W.	5.15 p.m.	12·7	18·97	34·27	25·91

Station V., 53° 53′ N. ; 4° 46′ W. 28/10/13 (9.45 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·1	18·97	34·27	25·83
30	12·9	18·97	34·27	25·87
60	12·95	18·96	34·25	25·84

Station VI., 53° 43′ N.; 4° 44′ W. 28/10/13 (11 a.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·45	19·01	34·34	25·81
30	13·2	18·99	34·31	25·84
60	13·2	18·99	34·31	25·84

Station VII., 53° 33′ N.; 4° 41′ W. 28/10/13 (12.15 p.m.)

Depth (metres)	T°	Cl°/oo	S°/oo	σ_t
0	13·7	18·99	34·31	25·73
30	13·6	18·99	34·31	25·75
65	13·4	18·99	34·31	25·79

Stations VIII. to XXIV. Surface observations only.

Station.		Date and Time.		T°	Cl°/oo	S°/oo	σ_t
VIII.	53°27′N.; 4°5′W.	28.10.13	p.m. 3.45	13·2	18·90	34·14	25·71
IX.	53°31′N.; 3°31′W.	29.10.13	a.m. 9.15	13·1	18·83	34·02	25·64
X.	53°37′N.; 3°45′W.	29.10.13	10.20	13·15	18·96	34·25	25·80
XI.	53°43′N.; 3°58′W.	29.10.13	11.20	13·2	18·98	34·29	25·82
XII.	53°48′N.; 4°12′W.	29.10.13	p.m. 12.15	13·2	18·99	34·31	25·84
XIII.	53°54′N.; 4°27′W.	29.10.13	1.15	12·95	18·97	34·27	25·86
XIV.	54°32′N.; 4°37′W.	30.10.13	a.m. 9.30	12·4	18·99	34·31	25·99
XV.	54°37′N.; 4°45′W.	30.10.13	10.25	12·5	18·94	34·22	25·90
XVI.	54°35′N.; 4°27′W.	31.10.13	8.50	12·6	18·93	34·20	25·87
XVII.	54°34′N.; 4°12′W.	31.10.13	9.50	12·5	18·94	34·22	25·90
XVIII.	54°32′N.; 3°55′W.	31.10.13	10.45	12·6	18·93	34·20	25·87
XIX.	54°29′N.; 3°43′W.	31.10.13	11.15	12·7	18·93	34·20	25·85
XX.	54°24′N.; 3°57′W.	31.10.13	p.m. 12.20	12·4	18·94	34·22	25·92
XXI.	54°20′N.; 4°13′W.	31.10.13	1.0	12·6	18·97	34·27	25·93
XXII.	54°15′N.; 3°57′W.	1.11.13	a.m. 7.25	12·4	18·95	34·23	25·94
XXIII.	54°10′N.; 3°42′W.	1.11.13	8.25	12·6	18·89	34·13	25·82
XXIV.	54°5′N.; 3°27′W.	1.11.13	9.20	11·9	18·57	33·55	25·51

December 2 to 5, 1913.

Stations I. to IV., 2/12/13. Surface observations only.

Station.		Time.	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
I.	54°N. ; 3°30′W.	11.45 a.m.	9·3	18·50	33·42	25·86
II.	54°N. ; 3°47′W.	1.0 p.m.	10·0	18·83	34·02	26·21
III.	54°N. ; 4°4′W.	2.15 p.m.	10·2	18·88	34·11	26·24
IV.	54°N. ; 4°20′W.	3.25 p.m.	10·8	19·00	34·33	26·30

Station V., 53° 53′ N. ; 4° 46′ W. 5/12/13 (9.40 a.m.)

Depth (metres)	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
0	10·85	18·95	34·23	26·23
30	10·4	18·93	34·20	26·28
49	10·85	18·94	34·22	26·21

Station VI., 53° 43′ N. ; 4° 44′ W. 5/12/13 (10.50 a.m.)

Depth (metres)	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
0	11·2	19·04	34·40	26·29
30	10·83	19·04	34·40	26·36
52	10·85	19·03	34·38	26·35

Station VII., 53° 33′ N. ; 4° 41′ W. 5/12/13 (12.5 p.m.)

Depth (metres)	T°	Cl°/$_{oo}$	S°/$_{oo}$	σ_t
0	11·0	18·96	34·25	26·21
30	10·46	18·97	34·27	26·33
60	10·83	18·96	34·25	26·24

Surface Salinities at Stations I-XXIV at the "Quarterly" Cruises of 1912 and 1913.

Station	1	2	3	4	5	6	7	8	9	10	11	12
1912												
May	33·28	33·49	33·91	34·40	34·49	34·54	34·47	33·86	32·90	33·68	33·78	34·40
July (August)	33·28	33·86	34·29	34·29	34·36	34·40	34·38	—	—	33·96	34·23	34·36
November	32·95	33·33	33·98	34·18	34·31	34·43	34·18	34·16	32·97	33·82	34·22	34·36
1913												
February	32·66	33·96	34·31	34·36	34·52	34·56	34·16	34·18	34·20	34·29	34·34	34·45
May	32·77	34·02	34·23	34·42	34·43	34·52	34·43	34·33	33·89	34·22	34·38	34·45
July (August)	33·55	33·69	33·78	34·11	34·40	34·40	34·38	34·05	33·10	33·44	33·68	34·34
November	33·66	34·13	34·27	34·27	34·27	34·34	34·31	34·14	34·02	34·25	34·29	34·31

Station	13	14	15	16	17	18	19	20	21	22	23	24
1912												
May	34·51	33·93	33·75	33·17	33·86	33·80	33·10	33·71	34·13	33·51	33·26	32·86
July (August)	34·34	33·82	33·53	33·71	33·64	33·62	33·51	33·68	33·96	33·73	33·51	33·03
November	34·33	34·27	34·07	33·68	33·84	33·71	33·03	33·31	34·00	34·04	33·69	32·99
1913												
February	34·38	34·33	—	—	33·33	32·97	32·61	33·01	34·07	*34·34	*34·07	*31·13
May	34·51	34·33	33·78	33·57	33·55	33·71	33·01	33·44	34·05	33·55	33·60	33·22
July (August)	34·36	34·22	34·18	34·09	34·09	33·64	33·64	33·75	34·11	33·78	33·91	33·62
November	34·27	34·31	34·22	34·20	34·22	34·20	34·20	34·22	34·27	34·23	34·13	33·55

* Stations 22A, 23A, and 24A. See particulars of February cruise.

THE POSITION OF THE ISOTHERMS IN THE NORTH ATLANTIC DURING 1907-1913.

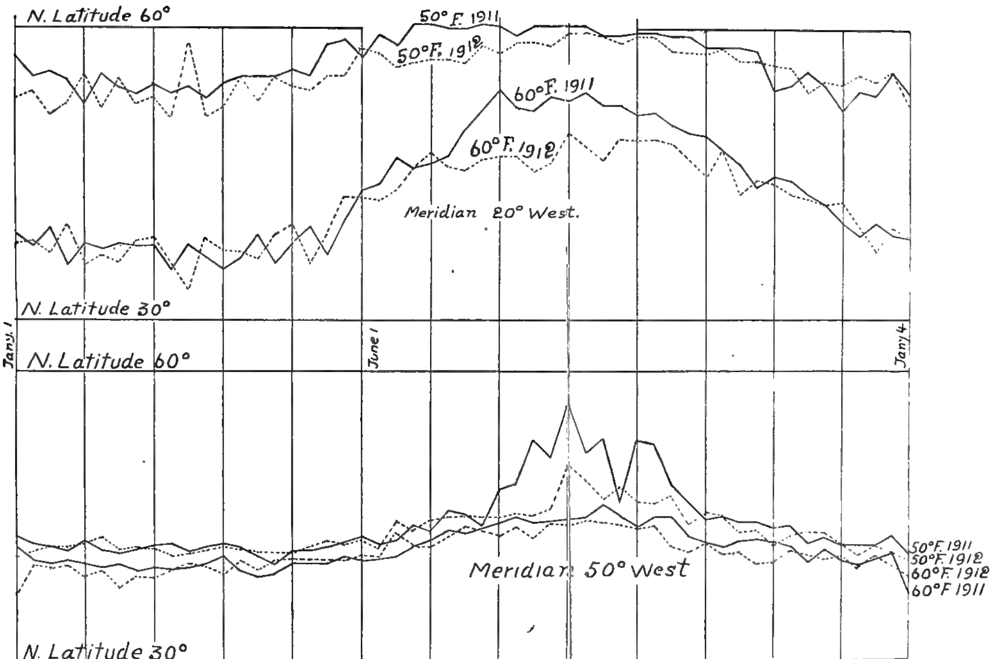
The view has frequently been expressed in these Reports that the movements of water in the Irish Sea, as indicated by the salinity changes, serve as an index to the seasonal changes in the North Atlantic. The detailed observations of salinities in the open ocean necessary to test the correctness of this view are not at present available, but it seemed possible that some help could be obtained from the numerous temperature observations which are constantly being made and summarised week by week, in the form of isotherms of sea temperature, and published on the Pilot Charts issued monthly by the Meteorological Office. It is probable that the relative position of these isotherms is to some extent dependent upon the relative position of the warm salt water of southern origin.

It is not easy, however, to get a comprehensive view of a large number of these isotherms, and recourse had to be had to a graphical method of summarising them.

The first method tried was that of making a diagram for meridian 20° W. and meridian 50° W., in which the positions of the isotherms for 50° and 60° were plotted in a co-ordinate system, in which the abscissae were weeks, and the ordinates the distances of the isotherms North of Latitude 30°. These distances were obtained by direct measurement from the charts. As the scale of the maps on the earlier charts was different from that on the charts as issued at present, they were reduced by a graphical method to the scale of the charts as at present published before being entered on the diagram.

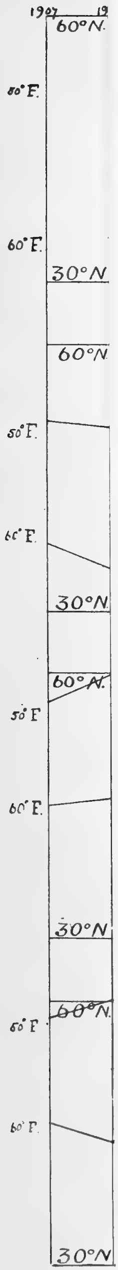
In this way a curve was obtained for each isotherm for each year, each being drawn in ink of a different colour. Even then, however, although there were often consider-

[illegible]



Positions of isotherms for 50° and 60° F. at Meridians 20° W. and 50° W. during 1911–1912

CHART I. North Atlantic Ocean. Variation of temperature from week to week throughout the year.



1907
19
60°N.
50°F.
60°F.
30°N
60°N
50°F.
60°F.
30°N.
60°N.
50°F
60°F.
30°N
60°N.
50°F
60°F.
30°N

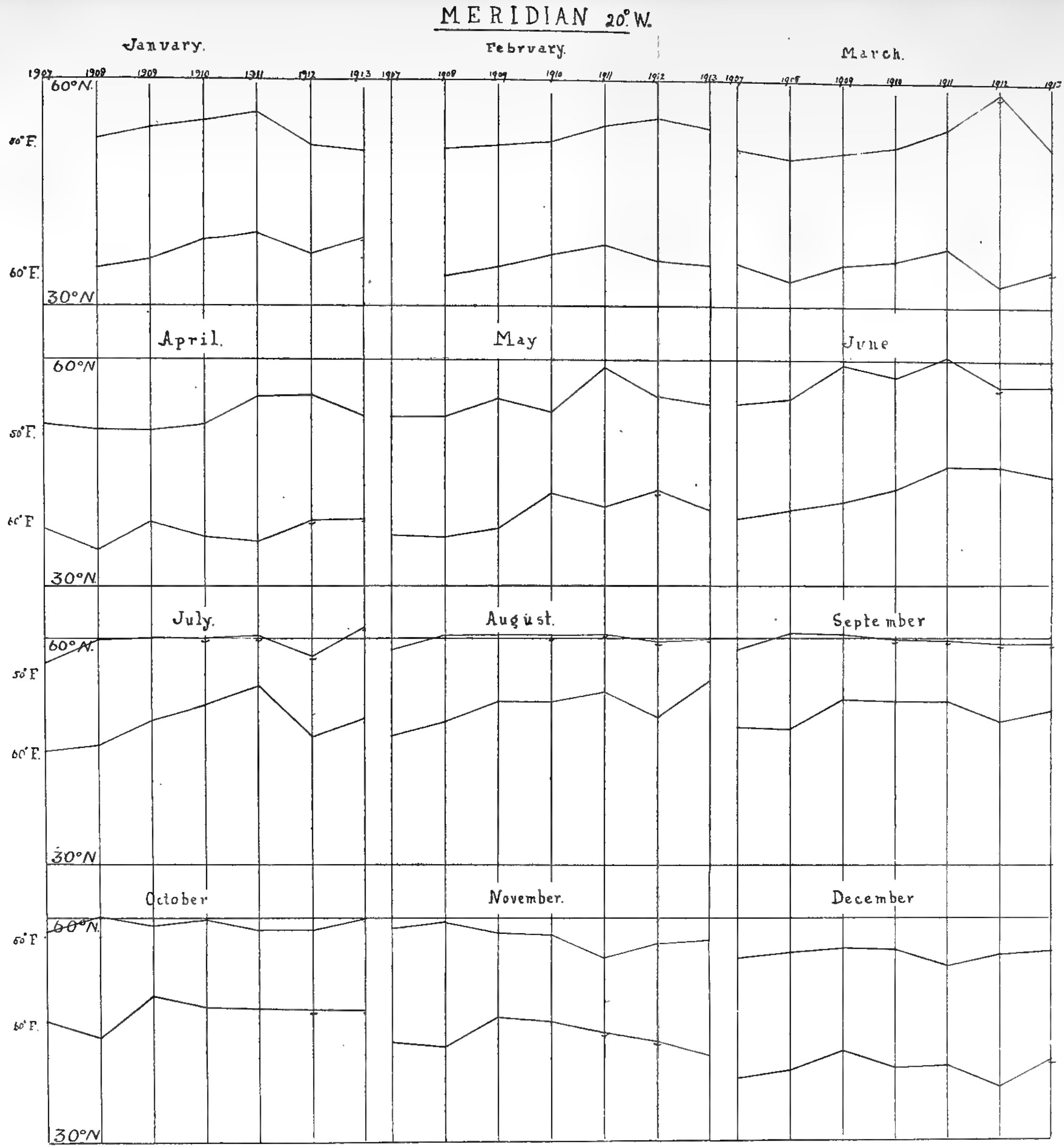
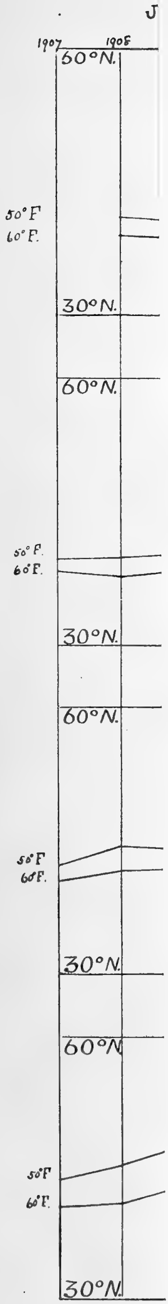


CHART II. North Atlantic Ocean. Variation of temperature from year to year.


J
1907
1908
60°N.
50°F
60°F.
30°N.
60°N.
50°F.
60°F.
30°N.
60°N.
50°F
60°F.
30°N.
60°N
50°F
60°F.
30°N.

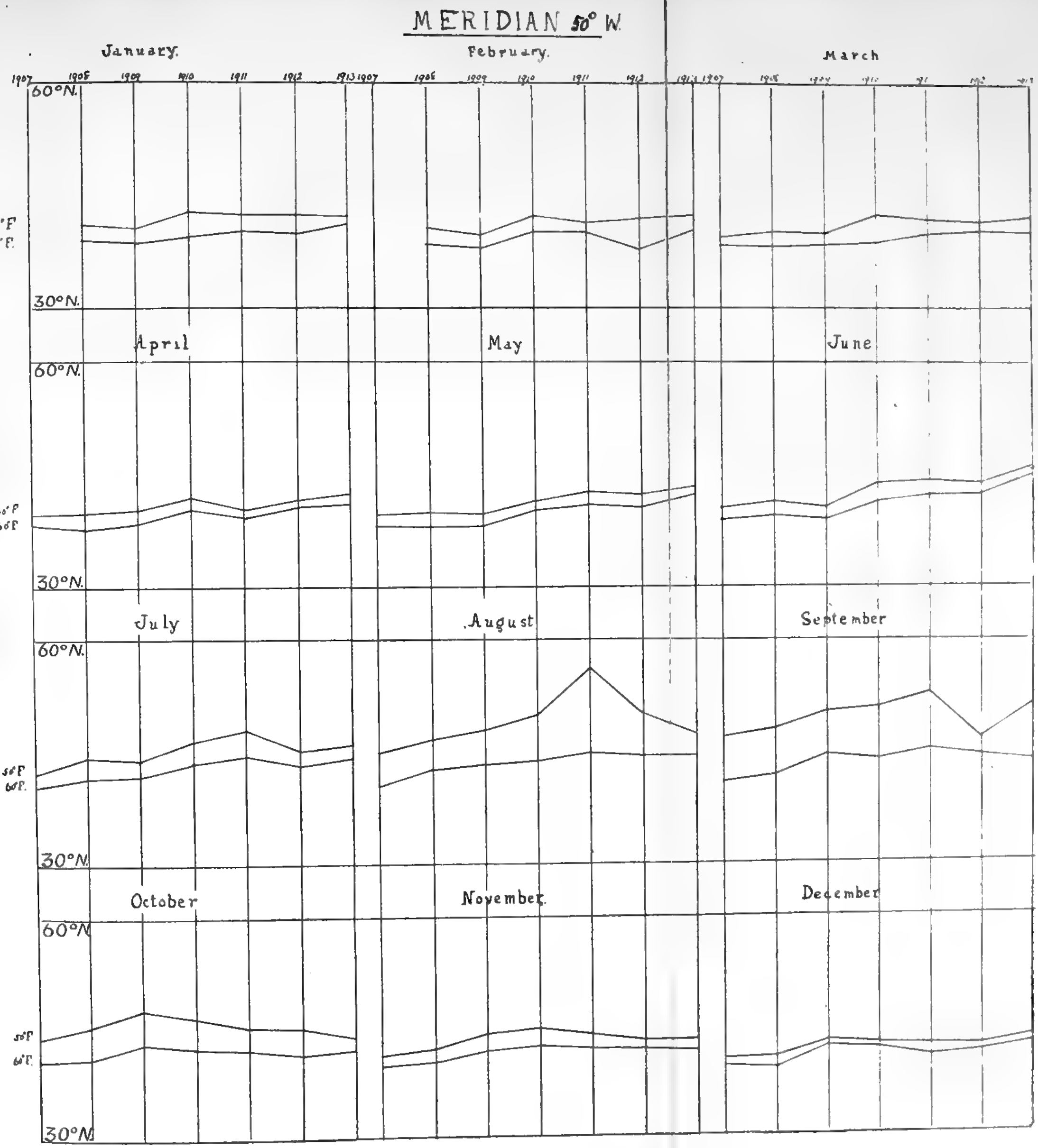


CHART III. North Atlantic Ocean. Variation of temperature from year to year.

able differences in the curves, the diagram was too crowded for this method of treatment to be satisfactory. The curves for two years are shown on the annexed diagram to illustrate the results obtained by the method. All the other curves were of a similar character, and show that the isotherms are farthest to the North about July or August, and farthest South about the end of April, although in the case of meridian 50 their position changes very little from the beginning of January to the beginning of June. Another noticeable feature is that there are very marked changes in the positions of the isotherms from week to week, changes which are so great that it is hardly possible to ascribe them to corresponding changes in salinity. This makes it seem very doubtful whether any safe conclusions can be drawn with regard to the position of the salter southern water from these observations of surface temperatures. The temperature at some moderate depth below the surface would probably be free from these sudden fluctuations, and might furnish the desired information.

Another method of graphical representation has also been tried, which, on the whole, gives a better idea of the changes being studied. Separate diagrams have been drawn for each month, in which the positions of the isotherms in the middle of the month have been plotted as ordinates against years plotted as abscissae. Each curve, therefore, represents the change in the position of an isotherm at corresponding times over a period of years.

The curves obtained are shown in the diagrams, but it is not easy to make much of them. All that can be safely said is that there is no apparent correspondence between them and the salinity changes which have been observed in our area of the Irish Sea over the same term of years.

THE PLANKTON ON THE WEST COAST OF SCOTLAND IN RELATION TO THAT OF THE IRISH SEA.—Part IV.

By W. A. Herdman, F.R.S., and Wm. Riddell, M.A.

We have now completed seven years (1907-1913 inclusive) observations on the summer plankton in the seas to the West of Scotland; and, as the British Association meeting in Australia in 1914 renders it impracticable to carry on work from the "Runa" in the coming summer, this seems a fitting opportunity to close this series of observations, and draw such conclusions as we can.

In our first Part* we dealt with the work carried on during the first four summers (1907-1910 inclusive), and showed:—

1. That a considerable difference existed between the summer plankton in Hebridean Seas and that of the Irish Sea at the same time.
2. That the phyto-plankton, which had disappeared from the Irish Sea by July, was still present in some parts of the Hebrides.
3. That some localities, in the Hebrides, not far apart, differ very considerably in the nature of their plankton at the same time of year.
4. That there is a constancy year after year in the nature of the plankton at some localities at corresponding times.

In that report we gave evidence to show that "off the north-west coast of Scotland, at one time of year (July) in several successive seasons, the plankton, as sampled by vertical hauls, was of different types (zoo- or phyto-

* This Report for 1910, p. 60.

plankton and neritic or oceanic) in different localities, but preserved a fairly constant character in each."

In our second Part, dealing with the observations made from the "Runa" in the summer of 1911, it was shown that in some localities, such as the north end of the Sound of Mull and the sea around the Small Isles, the phyto-plankton formerly present was replaced by zoo-plankton, and that the species were more oceanic in type. It was found, however, that still further North, off the north coast of Scotland, and in the Shetland Isles, the phyto-plankton still prevailed even as late as the middle of August. The facts put forward then still seemed to support the view that the most probable explanation of the greater number of Diatoms in the Scottish Seas in summer is that the phyto-plankton remains longer and passes off more slowly as one goes further North.

Our third Part, published in last year's report, dealt with the observations made from the yacht in the summer of 1912, and again showed, as in 1911, a zoo-plankton with strongly-marked oceanic elements around the North of Mull, where, in 1909 and 1910, we had a more neritic phyto-plankton. During this summer (August, 1912), the Atlantic water carried such oceanic organisms as *Doliolum tritonis* and *Cupulita sarsi* as far in as the channel between Mull and Ardnamurchan. Some phyto-plankton was, however, found in August, in the outer Hebrides and in the Sound of Mull. We attributed the greater prevalence of zoo-plankton in part to the fact that in 1912 our observations commenced a month later than in the previous summers, and in part to an unusual influx of Atlantic water, of which there seemed to be abundant evidence.*

We may remark at once that our observations this year

* See last Report, p. 188.

(1913), as will be shown in detail below, agree rather with those of the last two years than of the preceding period (1907-1910).

Cruise of 1913.

On the S.Y. "Runa" we left Port Erin, Isle of Man, in the night of July 9th, arrived in Lowlandman's Bay, Jura, in the afternoon of July 10th, and after visiting Oronsay, reached Oban in the evening of July 11th; took Mr. A. O. Walker and Professor R. Newstead on board, and after dredging off Lismore and in the Sound of Mull, reached Tobermory at 5 p.m., on July 12th, where we found mackerel fishing in the bay, and *Calanus* in great abundance in the plankton nets (see below).

On July 14th, we were dredging and taking plankton hauls off Ardnamurchan, on July 15th, the same up Loch Sunart, and on July 16th, the same again in the Sound of Mull. On July 17th, took in coal and water, and new dredge made by blacksmith; left Mr. Walker at Tobermory, and sailed in afternoon for West of Mull—thick fog round Treshnish Isles and Loch Tuadh; anchored in Soriby Bay, Ulva. On July 18th, explored several of the Treshnish Isles, and reached the Sound of Iona in the evening. July 19th, working round Staffa—large haul of *Calanus*—returned to Sound of Iona for Sunday.

On July 21st, left Iona for Loch Scridain—large haul of *Calanus*—landed at Bunessan, Mull, in evening. July 22nd, occupied on shore exploring Eocene Leaf-bed at Ardtun. July 23rd, Bunessan to Gott Bay, Tiree; and July 24th, dredging and plankton fishing between Tiree and Treshnish Isles, then landed on Hyskeir and arrived at Canna in evening. July 25th, dredging, &c.,

between Canna and Rum and around Muck Island; arrived Tobermory in evening. July 26th spent in dredging and plankton work up Loch Sunart—anchored off Dorlinn for Sunday. On July 28th, returned to Oban to land Professor Newstead.

On July 29th, joined by rest of party, and went on by Sound of Mull to Tobermory. July 30th, from Tobermory by Ardnamurchan, Canna, and West of Skye to Loch Harport. On July 31st, by Neist Point and Dunvegan to the Shiant Isles—on shore in afternoon—anchored for night off East beach on Garve Eilean. August 1st, on shore at Shiants—in afternoon dredging on East Shiant Bank—arrived Stornoway at night. August 2nd and 3rd at Stornoway—visited Callernish on Loch Roag.

On August 4th, left Stornoway for the East Shiant Bank—dredging and plankton work—anchored for night in Loch Shell, Harris. August 5th, dredging in Loch Shell, and also in Minch, N.W. of Skye; anchored for night in Port Erisco, Duntulm. On August 6th, went to Ascrib Islands, in afternoon dredged across mouth of Loch Snizort, between Ascribs and Vaternish Point (obtained "*Syntethys*"), anchored at Uig in evening. On August 7th, dredged again off mouth of Loch Snizort and onwards to Dunvegan Loch. August 8th, left Dunvegan and dredged southwards along west coast of Skye by Neist Point to Tarner Island, Loch Bracadale. On August 9th, continued to dredge at intervals onwards to the South towards Canna. Arrived Tobermory for Sunday.

August 11th, after taking in coal and water, and repaired dredge, did plankton work off Ardmore and off Ardnamurchan, anchored for night in Loch Scavaig, Skye. August 12th, dredging and plankton work off Rum—

anchored in Loch Scresort. August 13th, dredging East and South of Eigg, also in Sound of Sleat, near Armadale —anchored off Isle Ornsay. August 14th, passed through "Narrows of Skye," and dredged off Croulin More, and North of Croulins (got "*Syntethys*")—anchored in Loch-na-Beiste. On August 15th, dredged again North of Croulins, for "*Syntethys*," and northwards along coast—anchored off Shieldag, Loch Torridon. August 16th, dredged at various points in the Inner Sound, between Loch Torridon, South Rona, and Gairloch—anchored off Flowerdale, Gairloch, for Sunday. August 18th, trawled in Strath Bay, Gairloch, dredged southwards along coast, and anchored at Tosgach. August 19th, dredging North of Croulins for "*Syntethys*"—anchored at night in Loch-na-Beiste.

On August 20th, called at Kyleakin, passed South through "Narrows of Skye," to Loch Hourn, dredged and took plankton hauls in outer and middle lochs. August 21st, dredged in Loch Hourn and Loch Nevis, and anchored in Tarbet Bay, Loch Nevis. August 22nd, ran for shelter to Isle Ornsay. August 24th, from Isle Ornsay to Tobermory. August 25th, took in coal and water, and worked down to Oban. August 26th, dredging off Lismore for *Funiculina*, anchored Loch Buie. August 27th, Loch Buie to Oronsay, and then on through Sound of Islay to anchorage off McArthur's Head. August 28th, Sound of Islay by Gigha and Mull of Cantyre to Larne. August 29th, left Larne Harbour 6 a.m., arrived in Port Erin Bay at 3.30 p.m.

During this cruise of over 1,600 miles, physical observations on the temperature and salinity of the water were taken by George A. Herdman on the same lines as in the previous year, and a list of these observations will be found on pp. 305-306. Samples of water were also bottled at 35

"Runa," 1913. Physical Observations.

Date.	Time.	Locality.	Thermometer.	Aräometer.	Water Bottle Sample. Cl. °/$_{oo}$.	S°/$_{oo}$.	σ_t
July 10	7.45 a.m.	Black Hd. bearing W. by S., 4 miles off	11·8°C.	26·7	—	—	—
	10.0 a.m.	On course	12·2	26·4	—	—	—
	12.30 p.m.	Off Cantyre	10·9	26·9	—	—	—
	3.30 p.m.	Off Gigha	11·4	26·3	—	—	—
	6.0 p.m.	Lowlandman's Bay, Jura	11·1	26·3	—	—	—
,, 11	11.15 a.m.	White Farland Bay, Sd. of Islay	10·7	26·3	—	—	—
	3.30 p.m.	Off E. of Colonsay	12·4	26·3	18·72	33·82	25·62
	7.0 p.m.	W. of Bhaic Island	11·0	26·2	—	—	—
,, 12	1.0 p.m.	Off Ardtornish	11·2	26·0	—	—	—
,, 14	—	Off Ardnamurchan	11·8	27·0	[bottle	broken].	
,, 17	2.30 p.m.	Off Cailliach, Mull	11·8	27·0	18·97	34·27	26·08
,, 18	2.30 p.m.	Off Treshnish Ids,	11·6	26·9	—	—	—
,, 19	12.0 noon.	Off Iona	12·4	26·7	18·87	34·09	25·82
	5.0 p.m.	Off Staffa	12·3	26·8	—	—	—
,, 21	11.0 a.m.	Entrance to L. Scridain	11·7	27·0	18·91	34·16	26·01
,, 23	11·0 a.m.	N. of Iona	12·1	26·8	18·99	34·31	26·05
,, 24	3.0 p.m.	N. of Coll	13·4	26·8	(19·48	35·19	26·48)*
,, 25	10.0 a.m.	Off Canna	12·15	26·9	19·04	34·40	26·02
	4.30 p.m.	Off Ardnamurchan	12·5	26·7	—	—	—
,, 26	11.30 a.m.	Outer Loch Sunart	12·4	26·2	18·63	33·66	25·49
,, 27	4.0 p.m.	Off Eilean-nan-Eildean, near Dorlinn	12·15	26·1	—	—	—
28	10.15 a.m.	Between Lismore and Kerrera	11·5	26·3	18·38	33·21	25·31
30	11.0 a.m.	Off Ardnamurchan	13·11	26·4	[bottle	broken]	
	3.0 p.m.	Between Canna and Skye	13·09	26·9	—	—	—
,, 31	10.45 a.m.	Off Neist Lighthouse	12·23	27·0	—	—	—
August 1	9.0 a.m.	Off Shiants	11·51	27·3	19·21	34·70	26·47
	9.0 p.m.	Off Stornoway	14·02	27·0	—	—	—

*Stopper defective.

"Runa," 1913. Physical Observations—*Continued.*

Date.	Time.	Locality.	Thermometer.	Aräometer.	Water Bottle Sample. Cl. °/₀₀.	S°/₀₀.	σ_t
August 4	11.15 a.m.	Shiant East Bank	12·85	27·3	—	—	—
" 5	3.0 p.m.	5 miles S. of Glas Island	11·23	27·5	19·18	34·65	26·47
" 6	10.30 a.m.	Mouth of Loch Snizort	11·14	27·5	—	—	—
" 7	1.30 p.m.	Mouth of Loch Dunvegan	11·55	27·3	—	—	—
" 8	1.30 p.m.	Off Neist Point	12·85	27·0	19·10	34·51	26·06
" 9	11.0 a.m.	Off entrance to Loch Ainnart, Skye	12·29	27·1	—	—	—
	4·0 p.m.	Off Ardnamurchan	12·86	27·1	19·08	34·47	26·04
" 12	12·30 p.m.	Near Canna and Rum	12·95	26·8	18·98	34·29	25·87
" 13	1.30 p.m.	S. of Eigg	12·36	27·0	18·98	34·29	26·04
" 14	12.30 p.m.	Off Croulin More	14·39	26·6	18·87	34·09	25·42
" 15	11.30 a.m.	N. of Croulins	13·21	26·7	—	—	—
	2.30 p.m.	Off Ru Ard Ghlas, Rona Sound	11·50	27·1	18·99	34·31	26·17
" 16	10.30 a.m.	Loch Shieldag	13·17	26·9	—	—	—
	3.30 p.m.	Between Torridon and Gair Loch	12·40	26·9	18·91	34·16	25·88
" 18	2.30 p.m.	Grey Nose S. towards Lon-Ban	13·40	26·6	18·93	34·20	25·71
" 19	10.45 a.m.	N. of Croulins towards Cow Id.	12·49	26·7	18·83	34·02	25·75
" 20	12.45 p.m.	Loch Hourn	13·50	26·5	—	—	—
	4.30 p.m.	Middle Loch Hourn	12·59	26·5	18·75	33·87	25·62
" 24	8.0 p.m.	Tobermory Bay	12·81	26·6	—	—	—
" 25	1.10 p.m.	Off Tobermory	12·90	26·7	18·93	34·20	25·81
	4.15 p.m.	Lynn of Lorn	12·83	26·2	18·48	33·39	25·21
" 26	2.30 p.m.	Between Oban and Lismore	12·73	26·4	18·70	33·78	25·52
" 27	11.0 a.m.	Between Mull and Colonsay	13·27	26·5	18·84	34·04	25·61
	4.0 p.m.	Between Oronsay and Sd. of Islay	14·43	26·4	18·88	34·11	25·44
" 28	8.30 a.m.	Off McArthur's Head	12·99	26·6	18·85	34·05	25·68
	1.30 p.m.	W. of Cantyre Lighthouse	12·51	26·7	18·85	34·05	25·77
	3.0 p.m.	Between Cantyre and Larne	13·86	26·4	18·83	34·02	25·49
	5.0 p.m.	Off Larne	13·25	26·6	18·97	34·27	25·80
" 29	6.0 a.m.	Off Muck Island	12·70	26·7	18·94	34·22	25·86
	12.0 noon	On course to Bradda	13·42	26·6	18·98	34·29	25·78
	3.0 p.m.	Off Bradda	14.55	26·4	19·00	34·33	25·57

localities, and these have been examined by the method of titration by Professor Henry Bassett, who has kindly supplied the list of determinations which we have added in the three right-hand columns (pp. 305-306).

In all, 49 hauls of the plankton nets* were taken during the cruise. Of these, 13 were vertical hauls of the Nansen net, the deepest being from 140 fathoms off the Sound of Rona, and 36 were horizontal hauls, mostly at the surface: 22 of our surface hauls were taken with the larger Nansen net, measuring 1 metre in diameter of mouth.

The complete list of the plankton hauls is given on pp. 308-309, arranged chronologically and with the same indications of amount and nature that were given in the corresponding table in our last report.

It is obvious, on a comparison, that these series of gatherings viewed as a whole are very much more zoo-planktonic than those of any previous year during the period of our observations.

Comparison of Gatherings.

We may now examine and compare some of the more noteworthy hauls:—

We have two vertical hauls from precisely the same deep hole (108 fathoms) off Ardmore, at the north end of the Sound of Mull, the one taken nearly a month later than the other, which show the same fauna, but considerably reduced in amount at the later date:—

* The results of the dredging and trawling are not discussed in this paper. Some account of the more noteworthy animals obtained from the bottom will be found in "Spolia Runiana," II—in *Journ. Linnean Soc., Zool.*, 1914.

"Runa," 1913. Plankton Hauls.

Date.	Locality.	Depth.	Quantity.	Nature.	Remarks.
July 12...	Tobermory Bay	Surface	Large	Z ; N+O	Coarse net, 5 mins.
	Sound of Mull	Mid-water	Med.	Z ; N+O	(Walker's net).
" 13...	Tobermory Bay	Surface	Large	Z ; N+O	—
" 14...	Off Ardmore, Mull	108 faths.	Med.	Z+p ; O+n	(Vertical).
	Ardmore to Runa Gall	Surface	Large	Z ; O+n	(L. Nansen).
	Tobermory Bay	Surface	Large	Z ; O+n	—
" 15...	Loch Sunart	35 faths.	Sm.	Z+p ; O+N	(Vertical).
	Loch Sunart (mouth)	Surface	Large	Z ; O+N	(L. Nansen).
" 16...	Sound of Mull	Surface	Large	Z ; O+N	"
" 19...	Off Staffa	Surface	Large	Z ; O	"
" 21	Off Loch Scridain	Surface	Large (1,700 c.c.)	Z ; O+N	"
" 23...	Off Gott Bay, Tiree	Surface	Large	Z ; O	"
" 24...	Between Coll and Dutchman	Surface	Med.	Z ; O	(5 mins.)
	Sound of Coll	76 faths.	Med.	Z ; O	(Vertical).
	Sound of Coll	112 faths.	Med.	Z ; O	(Vertical).
	Off Hyskeir	Surface	Large	Z ; O	(L. Nansen).
" 25...	Off S.E. of Canna	138 faths.	Med.	Z ; O	(Vertical).
	S. of Muck	Surface	Large	Z ; O	(L. Nansen).
" 26...	Loch Sunart	Surface	Med.	Z ; O+N	(L. Nansen).
	Upper L. Sunart	44 faths.	Sm.	Z+p ; O+N	(Vertical).
" 30...	Off Talisker Bay	Surface	Large	Z ; O	(L. Nansen).
" 31...	Off Shiant Isles	Surface	Large	Z ; O	—
August 4...	Shiant East Bank	Surface	Med.	Z ; O	—
	Off Loch Shell	98 faths.	Sm.	Z+p ; O+n	(Vertical).
" 5...	Minch, off Loch Shell	Surface	Sm.	Z ; O	—
	Off Duntulm	Surface	Large	Z ; O	(L. Nansen).
" 6...	W. of Ascrib Islands	Surface	Large	Z ; O	(L. Nansen).
" 7...	Loch Dunvegan (mouth)	108 faths.	Sm.	Z ; O	(Vertical).

Z = Zoo-plankton ; P,p. = Phyto-plankton ; O = Oceanic ; N,n. = Neritic.

"Runa," 1913. Plankton Hauls—*Continued.*

Date.	Locality.	Depth.	Quantity.	Nature.	Remarks.
August 8...	Off Neist Point	Surface	Large	Z ; O	(L. Nansen).
,, 9...	Off Canna	125 faths.	Sm.	Z ; O	(Vertical).
,, 10...	Tobermory Bay	Surface	Large	Z ; O+N	—
,, 11...	Off Ardmore	108 faths.	Sm.	Z ; O+n	(Vertical).
	Between Ardmore and Ardnamurchan	Surface	Sm.	Z ; O+n	(L. Nansen).
,, 12...	North of Rum	139 faths.	Sm.	Z ; O	(Vertical).
,, 13...	South of Eigg	Surface	Med.	Z ; O	(L. Nansen).
,, 15...	Rona Sound	140 faths.	Med.	P+z ; O+n	(Vertical).
,, 16...	Loch Shieldag	Surface	Med.	Z ; O+N	(L. Nansen).
	Between Torridon and S. Rona	Surface	Med.	Z ; O	(L. Nansen).
	Off S. Rona Lighthouse	130 faths.	Med.	P+z ; O+N	(Vertical).
,, 17...	Gair Loch	Surface	Large	Z ; O+N	—
,, 19...	Between Croulins and Raasay	Surface	Med.	Z ; O	(L. Nansen).
,, 20...	Outer Loch Hourn	Surface	Large	Z ; O+n	(L. Nansen).
	Upper Loch Hourn (up L.)	Surface	Large	Z ; N+o	(Coarse).
	,, (down L.)	Surface	Large	Z ; N+o	(Coarse)
,, 22...	Off Isle Ornsay	Surface	Med.	Z ; O+N	(L. Nansen).
,, 24...	Tobermory Bay	Surface	Large	Z ; O+N	—
,, 25...	Sound of Mull	Surface	Med.	Z ; O+N	(L. Nansen).
,, 26...	Off Lismore	Surface	Med.	P+Z ; N	—
,, 27...	Between Oronsay and Sd. of Islay.	Surface	Large	Z ; O+N	(L. Nansen).

Z,z = Zoo-plankton ; P,p. = Phyto-plankton ; N,n. = Neritic ; O,o. = Oceanic.

Off Ardmore—108 fathoms.	July 14th.	August 11th.
Calanus finmarchicus	1,000	500
Pseudocalanus elongatus	12,500	7,600
Metridia lucens	100	—
Temora longicornis	2,000	—
Acartia clausi	6,800	1,000
Oithona similis	2,400	1,200
Nauplii	21,000	6,800
Nyctiphanes couchii	—	2
Diastylis lucifera	—	6
Decapod larvae	25	3
Euphausid larvae	5	—
Philomedes sp.	100	—
Sagitta	35	16
Polychaet larvae	200	—
Limacina	200	2,200
Lamellibranch larvae	1,800	600
Gastropod larvae	800	600
Medusoids	25	—
Tintinnidae	600	200
Oikopleura	400	200
Larval fish	2	—
Peridinium spp.	1,200	—
Ceratium furca	200	—
,, intermedium	200	—
,, macroceros	200	—
Coscinodiscus radiatus	2,400	800

It is very remarkable how consistent this reduction in numbers is. With the single exception of *Limacina*, which is an oceanic form brought in by the Atlantic water in swarms, all forms present on both occasions show in August only a fraction—frequently one-half or one-third —of the number present in July.

Somewhat similarly the two hauls from Loch Sunart, from 35 fathoms on July 15th, and from 44 fathoms on July 25th, show a considerable reduction in numbers on the latter date, and especially a disappearance of the phyto-planktonic element which drops from 6,300 to 400 individuals in the haul. Some of our other pairs of hauls (Sound of Coll and off Canna) exemplify, but less

markedly, this same relative reduction of the plankton in August.

Our deepest vertical haul, off Sound of Rona, 140 fathoms, on August 15th, is perhaps the nearest to a phyto-plankton of the whole series. There are as many species of Diatoms as of animals present, and the number of individuals of the former is, of course, many times greater. A neighbouring haul, also one of the deepest, taken the following day, off the north end of S. Rona, from 130 fathoms, is still more phyto-planktonic so far as numbers go—containing, as it does, 90,000 individuals of the Diatom *Corethron criophilum*.

It may be of interest to have these two hauls given here in full:—

	Off E. end of Sound of Rona, Aug. 15, 140 faths.	Off S. Rona, Aug. 16, 130 f.
ZOO-PLANKTON :—		
Calanus finmarchicus	1,200	1,000
Pseudocalanus elongatus	6,200	4,000
Oithona similis	1,000	1,800
Metridia lucens	200	100
Nauplii	2,600	4,200
Thysanoessa inermis	1	—
Sagitta	10	6
Tintinnidae	1,600	3,600
Gastropod larvae	—	200
PHYTO-PLANKTON :—		
Peridinium spp.	400	400
Asterionella japonica	—	200
Biddulphia spp.	—	400
Chaetoceras breve	400	—
,, criophilum	7,800	8,000
,, debile	7,200	800
,, decipiens	800	2,600
,, teres	600	—
Corethron criophilum	20,000	90,000
Coscinodiscus radiatus	600	400
Rhizosolenia semispina	600	1,400

Most of the other vertical hauls contain only a few hundreds or thousands of Diatoms in place of the millions present on some former occasions.

On looking over the remaining plankton hauls which are not vertical, but which are for the most part surface and horizontal, some taken with smaller and some with larger nets, there is no doubt that the outstanding character of the collection is the profusion of large Calanoid Copepoda. We came upon them in our first hauls in the Sound of Mull on July 12th, and they were also abundant outside Mull, at Tiree, off Hyskeir, off Eigg, around Skye, at the Shiant Isles, and the Ascribs, off South Rona and Raasay, up Loch Torridon and the Gairloch on the mainland, and in Loch Hourn and the Sound of Sleat off Isle Ornsay, and finally as far South as the sea between Colonsay and Islay, and as late as the end of August. In most of these localities *Calanus finmarchicus* was present in abundance, and also *Pseudocalanus elongatus*. Other abundant Copepoda are *Acartia clausi*, *Temora longicornis* and *Oithona similis*, sometimes *Centropages hamatus*, and usually large numbers of Copepod nauplii; but in all the cases of a really large gathering of macro-plankton, such as those shown in fig. 1, the conspicuous feature is the great abundance of *Calanus finmarchicus*. The three collecting jars seen along with the large Nansen net (diameter of mouth = 1 metre) contained catches of 1,700 c.c., 1,000 c.c., and 900 c.c. respectively, which consisted very largely of *Calanus finmarchicus*. The number of individuals present in the largest haul we have estimated to be about half-a-million.*

*As an example of the reliance that may be placed upon the relation between volumes and counts when dealing with such an organism as Calanus in plankton, it may be recorded that Professors Newstead and Herdman, when on board the yacht, counted the individuals in 8 c.c. of the plankton in the fresh condition on the evening it was taken, and found that quantity to contain 2,400 specimens of Calanus. The gathering taken from the same swarm a few days later, and amounting to 1,700 c.c., has now been estimated independently by Mr. Riddell, in the laboratory, as the result of the counting of several samples, to contain "fully half-a-million specimens of Calanus." On the basis of the count at Tobermory the large gathering would come out at 510,000—practically the same as Mr. Riddell's result.

To those who were present at the collecting of these samples, there seemed to be evidence of a connection between the large swarms of *Calanus* and the presence of mackerel which were being caught in the neighbourhood at the time, and which were found by dissection to be feeding on the Copepoda. In view of the importance of such facts, we think it worth while to quote here some notes written at the time, and since published elsewhere.

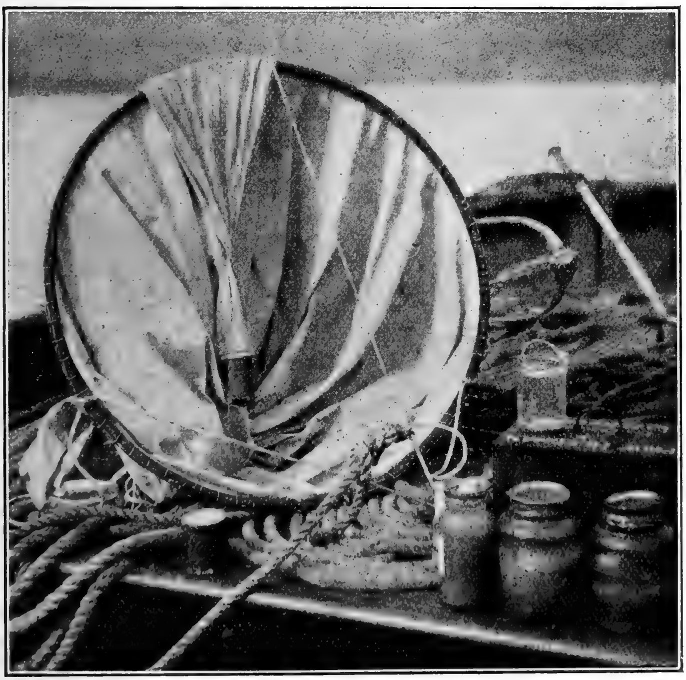


FIG. 1.—Large Nansen Net and Plankton Hauls taken with it, in July, near Tobermory.

"S.Y. 'Runa,' Tobermory, July 12th.

"On arriving in this bay last night we found that the local boats had been catching abundance of mackerel close

to. We bought some for supper (good fish for a halfpenny each), and on dissection found that the stomachs of all of them were crammed full of fresh-looking Calanus (the individual Copepods being for the most part distinct and perfect), along with a few immature Nyctiphanes and larval Decapods. Professor Newstead and my daughter then noticed, while fishing over the side of the yacht, about 8 p.m., that the gulls in the bay were feeding in groups around patches of agitated water evidently caused by shoals of fish. On rowing out to these we saw distinctly the mackerel, large and small, darting about in great numbers in the clear water, and we also noticed every here and there on the smooth surface of the water—it was a beautifully calm evening—innumerable small whirls or circular marks which, on looking closely, I found to be caused by large Copepoda close to the surface.

"About twenty years ago I sent a note to 'Nature,' from the yacht 'Argo,' in regard to large Copepoda (I think it was *Anomalocera* on that occasion, and the locality was further North, off Skye), splashing on the surface so as to give the appearance of fine rain; and this present occurrence at once reminded me of the former occasion, but here the Copepod was *Calanus finmarchicus* of large size and in extraordinary abundance. They could be clearly seen with the eye on leaning over the side of the boat, a small glass collecting jar dipped at random into the water brought out twenty to thirty specimens at each dip, and a coarse grit-gauze tow-net of about 30 cm. in diameter caught about 20 cubic centimetres of the Copepoda in five minutes. The mackerel were obviously darting about, occasionally leaping to the surface (which gave the gulls their opportunity) where the whirls, caused by the Copepoda, were thickest, and an examination of the stomach-contents of the fish on the yacht afterwards showed

us that the amount in one mackerel was about the same quantity as that caught by the tow-net in five minutes. Professor Newstead and I have made a count of 8 c.c. of the tow-net gathering, and estimate that it contains about 2,400 specimens of *Calanus*. This would give about 6,000 Copepods in the stomach of an average mackerel, or in a five minutes' haul of the tow-net, on this occasion.

"It may be added that these mackerel were evidently not being nourished in accordance with the views of Pütter, and were clearly able to fill their stomachs from the plankton around them."

The following note, written some weeks later, records the conclusion of the matter, so far as our summer observations went:—

"S.Y. 'Runa,' off Island of Eigg, August 12th.

"On getting back to Tobermory on Saturday, we found the plankton to be in marked contrast to its condition four weeks ago. The vast swarm of Calanoids has gone, and there are now no signs of mackerel feeding in the bay. In fact, the change has been noticeable for some days in the seas outside, and we have not been getting lately the large plankton catches that were usual in the latter half of July. On July 14th, a haul of the large surface tow-net, in the open sea off Ardnamurchan, gave such a huge catch of *Calanus* (about 1,000 c.c.) that we promptly took a second similar haul, and had it cooked as a sort of potted 'shrimp' confection for tea (sampled by ten persons, including the crew, who were much interested to try this new edible 'fish'); while on August 11th a haul of the same net, taken at the same spot, gave only a small catch of some 15 c.c., containing very few Calanoids, along with the usual scanty summer zoo-plankton."

It will be remembered that some years ago, Dr. E. J.

Allen and Mr. G. E. Bullen did some interesting work, at the Plymouth Marine Laboratory, demonstrating the connection between mackerel and *Calanus* and sunshine in the English Channel.

In an earlier part of the present volume, Mr. A. Scott has recorded that at the very time we were finding the mackerel feeding on *Calanus* in the Hebrides, he found them gorging on *Pleurobrachia* in the Irish Sea.

The fact is that although a fish like the mackerel or herring may have a normal or favourite food, it may on occasions be found associated with and devouring almost any larger form of the zoo-plankton which is locally abundant. If, as Pütter contends, the normal, generally distributed plankton of the sea, is not sufficient in amount to nourish a fish swimming through it haphazard, and taking what it can get from the water passing through its mouth, it becomes the more necessary for fish such as shoals of mackerel and herring to seek out and follow abnormal tracts of especially abundant and nourishing plankton, so as to appear in a locality where *Calanus*, for example, is swarming, and to migrate elsewhere when the Copepoda disappear—in a word, to *hunt* their food in place of *absorbing* it. These considerations give, of course, an entirely new importance to that irregular distribution of the plankton which is so marked a character of our coastal waters.

The only other organism that need be mentioned is the Pteropod *Limacina retroversa*. This first appeared in a gathering off Ardnamurchan on July 14th, and after that was found in most of the hauls taken in open water, such as the west coast of Mull, off Staffa, at Tiree, off Hyskeir, off the West of Skye, at the Shiant Isles, and elsewhere; but none were found up the Lochs or in the more sheltered localities. It was frequently present in

thousands in a vertical haul of the small Nansen net, the greatest number being 23,700, from 76 fathoms, in the Sound of Coll.

After *Calanus finmarchicus*, *Limacina retroversa* is perhaps the most distinctive feature of many of the gatherings—several of which, in fact, such as the haul taken off Neist Point on the West of Skye, on August 8th, consist chiefly of these two species.

All the horizontal hauls show a typical zoo-plankton with the exception of the gathering taken off Lismore in the Lynn of Lorn, on August 26th, which has a considerable admixture of phyto-plankton, as the following analysis of its contents shows:—

ZOO-PLANKTON.		PHYTO-PLANKTON.	
Calanus	few.	*Ceratium longipes*	fair number.
Oithona	fair number.	*Rhizosolenia shrubsolei*	many.
Acartia	fair number.	*Asterionella japonica*	few.
Pseudocalanus	few.	*Chaetoceras decipiens*	few.
Nauplii	fair number.	*C. spp.*	few.
Evadne	fair number.		
Oikopleura	many.		
Plutei	many.		
Medusoids	fair number.		

We have three surface hauls taken in Loch Hourn on the same day (August 20th) which may be put on record for comparison.

	Outer Loch Hourn (Large Nansen).	Upper L. Hourn (up.)	Upper L. Hourn (down).
Calanus	great number	few	few.
Pseudocalanus	very many	very many	very many.
Acartia	very many	very many	very many.
Oithona	very many	many	fair number.
Temora	—	many	—
Euphausid larvae	fair number	—	—
Nauplii	—	many	many
Evadne	—	very many	many.
Macruran larvae (*Pandalina*)	—	—	few.
Lamellibranch larvae	—	—	many.
Gastropod larvae	—	—	fair number.
Pleurobrachia	few	—	—
Oikopleura	—	fair number	—
Medusoids	fair number	—	—
Annelid larvae	—	fair number	many.
Fish Eggs	a few	—	fair number.
Fish larvae	—	—	a few.

It is not surprising that Outer Loch Hourn should be different in some respects from the Upper Loch, especially when the haul was taken with the large Nansen; but it is curious that the two hauls in the Upper Loch, both taken with the same coarse-meshed tow-net, in two consecutive quarters of an hour, the one up and the other down the same piece of water, should differ as these do in the case of *Temora*, *Oikopleura*, the fish eggs, and the Molluscan larvae.

Results in 1913.

We may now put briefly a few general results of this year's observations:—

We have again to notice the marked absence of phyto-plankton in 1913, as contrasted with the years 1907-1910.

The most southerly stations (Oronsay and Sound of Islay) were only examined late in August. *Calanus* was plentiful, also smaller Copepoda, and *Evadne* was common in Sound of Islay. There are no diatoms, whereas last year the gathering off Colonsay on August 27th was described as "a phyto-plankton with an admixture of some animals."

The gatherings from the Firth of Lorn area and Sound of Mull show very few diatoms until August. One haul off Lismore on August 26th contains a large amount of *Rhizosolenia* and a few *Chaetoceras* and *Asterionella*. No diatoms were observed at Ardmore on August 11th, and few in Loch Sunart on July 15th. The most marked phyto-plankton in the Nansen gatherings was on August 15th, off Rona Sound. Even this is not a pure phyto-plankton; it is a mixed plankton, containing a considerable amount of zoo-plankton. The same remark applies to a gathering off South Rona on the following day. The pre-ponderating forms here are oceanic, e.g., *Corethron*, *Chaetoceras criophilum*, *Ch. decipiens*.

This year we cannot make so generally the criticism which we made in our last report, that the gatherings are a month later than in 1907-1910. Thus our gatherings from the north end of the Sound of Mull are about the same date (latter half of July), as in the former years. The gathering from Hyskeir was on July 11th in 1910; this year it is July 24th, which might cause a distinct difference. A haul at the mouth of Loch Scridain on July 21st may be compared with that of August 12th, 1912, between Staffa and Lunga, and shows an even more marked zoo-plankton, and as regards this year's catches we have already drawn attention to the fact that of two hauls taken in the same locality on different dates, the later very often shows a marked diminution in the zoo-plankton.

The persistence of the change in type of the gatherings off Ardmore and in that neighbourhood since 1910 is remarkable.

Perhaps the most noteworthy point about this year's hauls is the presence of great numbers of *Calanus finmarchicus* practically everywhere throughout the area examined. *Calanus* was scarce only in two gatherings, one off Lismore on August 26th, and one in Upper Loch Hourn on August 20th, while as regards the latter locality, *Calanus* was common in Outer Loch Hourn on the same date.

As in 1911, *Limacina* has been common in many gatherings, and in much the same localities as in that year.

There is no trace this year of either *Doliolum* or *Cupulita*. *Metridia* occurs in a few gatherings: off Ardmore, July 14th, was its most southerly occurrence; it also occurred North of Rum on August 12th; in Rona Sound and off South Rona, August 15th and 16th, and at the Shiants on July 31st and Loch Shell on August 4th. *Corethron criophilum*, which is also an Atlantic form, was common about Rona Sound on August 15th and 16th.

General Conclusions.

We do not desire to change in any material respect the general conclusions that we arrived at in last year's report. We may quote in particular one paragraph which, with the exception of the final sentence receives further confirmation from this year's work. It is as follows:—

"We see no reason to modify our view that the spring phyto-plankton seems to remain longer in northern Scottish waters than it does in the Irish Sea. It probably disappears more slowly some years than others, and it certainly seems to be replaced more on some occasions than on others by invasions of oceanic zoo-plankton. This summer there seems to have been a well-marked invasion of this character to the North of Mull, carrying even such an Atlantic organism as *Doliolum* almost into the Sound of Mull."

In regard to the last sentence, *Doliolum* was present in 1912, while this year not a single specimen was seen. On the other hand the pelagic, oceanic Pteropod *Limacina*, which was present in quantity in 1911, and was totally absent from our Hebridean gatherings in 1912, was present in great abundance this year (1913) in all the open waters from Mull to the Minch, North of Skye. The occurrence of these two pelagic organisms, *Doliolum* and *Limacina*, may be regarded as equally affording evidence of an inflow of Atlantic water, and that the one should be carried in to certain waters one summer, and the other the following year, may be of no general significance, but may simply depend upon the abundance and distribution of these organisms in the outer area at the time when the inflow took place.

We may repeat what we stated last year in discussing the three kinds of sea-water, (1) Arctic, (2) Atlantic, and (3) Coastal, which may enter or affect the British seas, as

follows:—"The seas on the west coast of Scotland are on the border line of the last two kinds of water, and may be regarded as primarily an area of Coastal water which is, however, periodically invaded to a greater or less extent by bodies of warmer and salter Atlantic water carrying in oceanic plankton. The variations which we find in different years in the nature and amount of the plankton, at the same localities, no doubt depend upon the volume and period of such invasions. They may depend also upon other factors, such as the weather (temperature, sunshine, rainfall, wind, &c.) at the time, and previously."

To this we may now add that the presence of *Doliolum* last summer and not this, and of *Limacina* this summer and not last, is a good example of such variations in the oceanic invasions of zoo-plankton. The two summers were very different in character; 1912 was cold, wet and stormy, while 1913 gave us for the most part fine weather and calm seas; but although the two fine Augusts of 1911 and 1913 showed quantities of *Limacina* and the intermediate bad summer showed none, still we hesitate to do more than record the facts: there may be no connection between the weather and such variations in the plankton as we have observed.

We may remark, finally, that both (1) the lingering of the phyto-plankton in more northerly waters, with occasional very large swarms of diatoms, and (2) the oceanic invasions from the Atlantic constitute a marked difference between a collection of summer plankton from the West Coast of Scotland, North of the Mull of Cantyre, and a collection made at the same time from the more enclosed waters of the Irish Sea.

REPORT ON THE PERIODIC SAMPLES OF SHRIMPS FROM THE MERSEY ESTUARY.

By T. MONAGHAN,
Assistant Naturalist in the Fisheries Laboratory.

During 1913 and part of 1912 samples of shrimps were received periodically from the Fisheries Bailiff (Captain Eccles), which I examined and measured. The approximate averages of berried females, non-berried females, and males were also found for each sample. The samples were taken from the fishing grounds in the Rock Channel and the Crosby Channel, both of which may be spoken of as the "Mersey Estuary." On examining the shrimps individually it was found that the eggs were most abundant from January to August, and the proportion of the berried females then diminished from September to December. It will be noticed from the following tables that the samples were not sent for examination every month on account of difficulties in obtaining them, so that definite conclusions cannot yet be arrived at from the investigation. The data, however, are given here, and the observations will be continued with greater regularity this year. Table I gives the rough data. Table II gives the percentage of males, berried females, and non-berried females. The chart below represents the latter variation graphically.

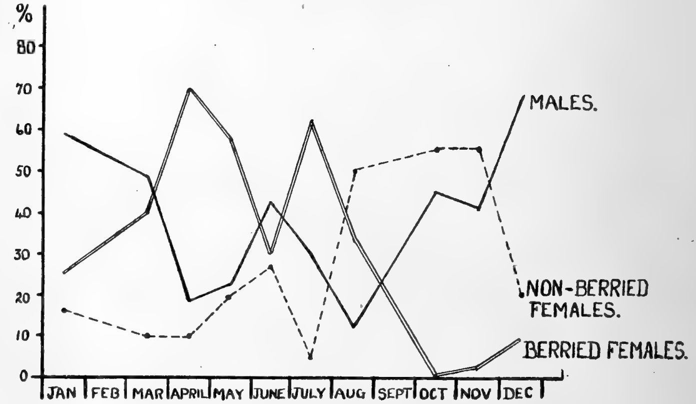


FIG. 1. Variation in the percentages of males, non-berried females, and berried females in shrimps caught in the Mersey estuary.

TABLE I.

Date.		No.	Average Length in mm.
1912. July 16th	Berried Females	128	75
	Non-berried Females	12	58
	Males	60	58
		200	
August 12th	Berried Females	411	70·95
	Non-berried Females	86	59
	Males	75	52·05
		572	
August 30th	Berried Females	40	66·8
	Non-berried Females	550	64
	Males	100	53·4
		690	
November 19th ...	Berried Females	9	76
	Non-berried Females	195	69
	Males	149	54
		353	
December 20fh ...	Berried Females	54	72·7
	Non-berried Females	132	67
	Males	412	52·8
		598	
1913. January 16th ...	Berried Females	264	69·95
	Non-berried Females	174	62
	Males	638	58·05
		1,076	
March 6th	Berried Females	410	66·05
	Non-berried Females	106	65·55
	Males	484	55·7
		1,000	
April 11th	Berried Females	574	62·55
	Non-berried Females	82	61·95
	Males	157	51·75
		813	
May 23rd	Berried Females	418	74·9
	Non-berried Females	135	60·15
	Males	158	55·2
		711	

Date.		No.	Average Length in mm.
June 20th	Berried Females	185	72·7
	Non-berried Females	163	56·7
	Males	265	51·25
		613	
October 10th ...	Berried Females	2	67·5
	Non-berried Females	303	64·95
	Males	162	58·15
		467	
October 20th ...	Berried Females	2	72·5
	Non-berried Females	501	61·65
	Males	491	51·95
		994	
December 11th ...	Berried Females	158	69·65
	Non-berried Females	328	64·75
	Males	1,336	55·3
		1,822	

TABLE II.

	Percentage of Males.	Percentage of Berried Females.	Percentage of Non-berried Females.
January, 1913 (1)	59·3	24·5	16·2
February	No. samples		
March, 1913 (1)	48·4	41·0	10·6
April, 1913 (1)	19·3	70·6	10·1
May, 1913 (1)	22·2	58·8	19·0
June, 1913 (1)	43·2	30·2	26·6
July, 1912 (1)	30·0	64·0	6·0
August, 1912 (2)	13·9	35·7	50·4
September	No samples		
October, 1913 (2)	44·7	0·3	55·0
November, 1912 (1) ...	42·2	2·6	55·2
December, 1912-13 (2)	72·2	8·8	19·0

HERRING INVESTIGATIONS (WITH DESCRIPTION OF A NEW FISH-MEASURING BOARD.)

By W. Riddell, M.A.

The present paper is a preliminary contribution to the biometric study of Irish Sea herring, with a view to discovering whether these show any sub-division into local "races," such as have been described by Heincke. So far a complete examination along the lines indicated by Heincke has not been made, only a few characters having been examined, but it is hoped in future work to carry out a more extended series of measurements, including the vertebral characters, on larger numbers of fish.

The characters so far examined have been as follows:—

1. Total length from extremity of snout to the vertical line joining the tips of the lobes of the caudal fin when in its natural position. [*T*].

2. Total length to base of tail. [*T. cd.*].

3. Length from tip of snout to beginning of dorsal fin. [*D*].

4. Length from tip of snout to beginning of pelvic fin. [*V*].

5. Length from tip of snout to anus. [*A*].

6. Lateral length of head. [*l. cp. l.*].

7. Number of keeled scales between anus and pelvic fins. [K_2].

In addition, the sex has been noted, and the condition of the gonads according to Hjort's scale. As regards the latter, I have included under V all cases where, even if the roe and milt were not actually flowing, the condition of the gonads showed that they were to all intents ripe, and the products would shortly be fit for extrusion.

As regards comparison of these characters, it will be seen from the tables that I have expressed *D*, *V*, *A*, and *l. cp. l.* in percentages of *T. cd.* instead of *T.* The latter seems to me much too uncertain a measurement to be taken as a standard. Even when the caudal fin is complete and in good condition, the position in which the lobes are placed for measurement will depend to a large extent upon the idiosyncrasies of the observer, while in many cases, especially with commercial samples, the fin is in such a bad state of preservation that any attempt at measurement becomes pure guesswork.

In all cases, however, I have given this measurement in the tables.

The samples examined are as follows :—

1. 12 fish from New Quay Head, November 7th, 1913.
2. 15 fish from New Quay, November 11th, 1913.
3. 10 fish from Penrhyn Weir, Bangor, November 17th, 1913.
4. 18 fish from Moelfre, November 20th, 1913.
5. 12 fish from New Quay, November 24th, 1913.
6. 13 fish from Penrhyn Weir, Bangor, November 24th, 1913.
7. 12 fish from New Quay Head, December 8th, 1913.
8. 10 fish from Moelfre, December 8th, 1913.
9. 18 fish from Penrhyn Weir, Bangor, December 9th, 1913.
10. 11 fish from Tremadoc Bay, December 18th, 1913.
11. 11 fish from Moelfre, January 6th, 1914.
12. 150 fish trawled off the Smalls Rocks, about 26th October, 1913.

I have grouped the first eleven samples together, as representing one shoal, for purposes of statistical examination. How far this is justified future investigations alone can show, but at present all the evidence at my disposal seems to show that these fish all belong to one shoal, whose spawning ground

is in Cardigan Bay, and perhaps also Carnarvon Bay. So far this spawning ground has not been found, but I hope to make a search for spawn next season.

In future seasons I hope to obtain larger samples of fish from the various places along the coast, with a view to discovering how far this grouping of the present samples is justified.

If we adopt this grouping, and regard the trawled herring separately, we shall find that there seems to be a significant difference in the mean as regards most of the measurements.

D. Here the 142 fish represented by the first lot of samples, which I shall in future term the "inshore fish," give a mean percentage of 51·74, with a standard deviation (σ) of 1·27 and a probable error (E) of $\pm$ 0·07. (All percentages are percentages of *T. cd.*, as noted above). The trawled fish have a mean of 52·81, $\sigma = 0{\cdot}98$, E = $\pm$ 0·05. Thus the difference in the means is 1·07, or more than fifteen times the larger E, and is therefore probably significant. If we adopt the formula ($\sqrt{E_1^2 + E_2^2}$) for the "standard error," this gives a value of 0·08; thus the difference of the means is more than thirteen times the standard error.

V. The inshore fish have a mean of 55·22, $\sigma = 1{\cdot}07$, E = $\pm$ 0·06. The trawled fish have a mean of 55·64, $\sigma = 0{\cdot}91$, E = $\pm$ 0·05. The standard error is 0·08, and the difference in the means, 0·42, is seven times E, and five times the standard error, and is thus also significant.

A. The inshore fish have a mean of 75·76, $\sigma = 1{\cdot}24$, E = $\pm$ 0·07. The trawled fish have a mean of 75·91, $\sigma = 1{\cdot}06$, E = $\pm$ 0·05. Here the standard error is 0·08, and the difference in the means is 0·15, only twice E, and is therefore probably not significant.

l. cp. l. The inshore fish have a mean of 21·58, $\sigma = 0{\cdot}92$, E = $\pm$ 0·04. The trawled fish have a mean of 22·22, $\sigma = 0{\cdot}77$, E = $\pm$ 0·04. Here the standard error is 0·05, and the

difference in the means is 0·64, sixteen times E, or thirteen times the standard error, and therefore significant.

K_2. Here the mean of the inshore fish is 14·02, $\sigma = 0{\cdot}84$, E $= \pm$ 0·04. The mean of the trawled fish is 13·91, $\sigma = 0{\cdot}69$, E=0·03. The standard error is 0·05, and hence the difference is not significant.

Thus out of these five characters three—*D*, *V*, and *l. cp. l.*—show differences which are probably significant, and two—*A* and K_2—show differences which cannot be so regarded.

Always assuming, therefore, that we are justified in regarding these inshore fish as belonging to one group, there seem to be grounds for regarding the two series as showing some degree of racial separation. The correctness of this conclusion will have to be tested next season on a larger number of fish with a more extended series of measurements. Both these groups belong to the winter herring; it is hoped in the coming season to make a detailed examination of the summer herring also. There is a further point to which I think attention might be directed in subsequent investigations. One or two of the characters show some indication of a sexual difference between members of the one race. Thus I have separated the two sexes of the inshore fish as regards *V*, with the following result:—

♂ :—Mean 76·01, $\sigma = 1{\cdot}36$, E $= \pm$ 0·1. (76 examples).
♀ :—Mean 75·5, $\sigma = 1{\cdot}02$, E $= \pm$ 0·08. (66 examples).

Here the difference in the means is five times the probable error, but the significance of this depends upon how far one can regard the two series as representing the sexes properly. Personally, I am not inclined to insist upon it, as the series are so small, but I think the point might be worth investigation when a larger number of fish are under examination. Such differences have already been described in the plaice by Duncker.

As regards the spawning of the inshore fish, it will be

noticed that none of the fish from further South than Tremadoc Bay are spent. A few fish received from near Aberdovey early in the season (not included in the tables) were also mostly full fish, only one being spent. But not all the fish North of Cardigan Bay are spent; thus while the majority of the fish from Moelfre are spent, the majority of those from Bangor are not. The actual spawning-grounds of these fish still remain to be discovered.

Table I.

(All measurements in the tables are in millimetres.)

½ mile E. of New Quay Head, November 7th, 1913. 4″ mesh.

			D		V		A		l.cp.l.				
No.	T.	T.cd.		% T.cd.		% T.cd.		% T.cd.		% T.cd.	K_2	s	g
1	262	230	117	50·9	131	56·9	172	74·8	46	20	14	♀	V.
2	260	222	116	52·2	122	54·9	170	76·5	46	20·7	14	♂	V.
3	256	221	119	53·8	125	56·5	174	78·7	46	20·8	13	♂	V.
4	255	223	116	52	123	55	166	74·4	46	20·6	14	♀	V.
5	252	221	112	50·6	123	55·6	170	76·9	47	21·2	15	♂	V.
6	250	220	111	50·4	122	55·4	169	76·8	47	21·4	14	♀	V.
7	250	219	115	52·5	122	55·7	165	75·3	45	20·5	12	♀	V.
8	250	218	113	51·8	119	54·5	164	75·2	45	20·6	14	♀	V.
9	250	217	112	51·6	120	55·3	165	76	45	20·7	13	♂	V.
10	250	213	115	53·9	119	55·8	164	77	45	21·1	14	♀	V.
11	249	212	109	51·4	114	53·7	163	76·8	43	20·3	15	♂	V.
12	248	214	114	53·2	117	54·6	163	76·1	46	21·5	14	♀	V.

New Quay, November 11th, 1913. 4″ mesh.

13	276	239	123	51·4	128	53·5	182	76·1	53	22·1	13	♀	V.
14	274	242	125	51·6	137	56·6	189	78·1	50	20·6	14	♂	V.
15	268	237	124	52·3	133	56·2	183	77·2	47	19·8	15	♂	V.
16	264	229	120	52·4	128	55·9	178	77·7	49	21·4	13	♀	V.
17	259	224	114	50·8	124	55·3	176	78·5	51	22·7	14	♂	V.
18	258	227	116	51·1	120	52·8	174	76·6	47	20·7	14	♂	V.
19	257	225	111	49·3	119	52·8	172	76·4	46	20·5	14	♂	V.
20	257	224	115	51·3	119	53·1	167	74·5	45	20·1	13	♀	V.
21	256	223	115	51·5	121	54·2	171	76·6	46	20·6	13	♂	V.
22	255	221	120	54·3	120	54·3	172	77·8	45	20·3	15	♂	V.
23	253	221	113	51·1	122	55·2	174	78·7	45	20·3	14	♂	V.
24	250	225	113	50·2	124	55·1	173	76·8	48	21·3	13	♀	V.
25	250	218	112	51·3	119	54·5	167	76·6	47	21·5	13	♀	V.
26	246	216	108	50	117	54·1	166	76·8	45	20·8	15	♂	V.
27	239	210	104	49·5	113	53·8	158	75·2	43	20·5	13	♂	V.

Penrhyn Weir, Bangor, November 17th, 1913.

28	276	244	127	52	131	53·5	184	75·4	50	20·5	15	♀	V.
29	262	231	122	52·8	129	55·8	175	75·7	50	21·6	15	♀	V.
30	255	225	118	52·4	126	56	172	76·4	47	20·8	15	♀	V.
31	253	225	116	51·5	128	56·8	172	76·4	48	21·3	15	♂	V.
32	253	223	117	52·4	119	53·3	165	73·9	48	21·5	15	♂	V.
33	249	217	114	52·5	125	57·6	165	76	47	21·6	13	♀	V.
34	248	217	114	52·5	119	54·8	167	76·9	50	23	15	♂	V.
35	248	214	112	52·3	121	56·5	164	76·6	47	21·9	15	♂	V.
36	246	218	118	54·1	125	57·3	168	77	49	22·4	14	♂	V.
37	242	213	108	50·7	116	54·4	158	74·1	45	21·1	14	♂	V.

Moelfre, November 20th, 1913.

38	272	239	121	50·6	139	58·1	184	76·9	52	21·7	15	♀	VI.
39	268	235	124	52·7	133	56·6	183	77·8	54	23	14	♂	VI.
40	264	234	120	51·3	131	55·9	172	73·5	52	22·2	14	♀	V.
41	263	230	120	52·1	130	56·5	172	74·7	52	22·6	15	♀	V.
42	262	235	121	51·5	130	55·3	175	74·4	50	21·2	14	♂	VI.
43	262	234	120	51·3	132	56·4	179	76·5	51	21·8	14	♂	VI.
44	259	226	120	53·1	127	56·2	175	77·4	49	21·6	14	♂	VI.
45	255	226	114	50·4	128	56·6	170	75·2	45	19·9	14	♂	V.
46	250	223	111	49·7	122	54·7	168	75·3	48	21·5	15	♂	VI.
47	249	213	114	53·5	118	55·4	164	77	47	22·1	15	♂	VI.
48	246	216	110	50·9	120	55·5	162	75	46	21·3	14	♂	VI.
49	245	214	114	53·2	120	56	163	76·1	48	22·3	14	♀	V.
50	245	214	111	51·8	119	55·6	164	76·6	48	22·4	15	♂	VI.
51	239	209	106	50·7	114	54·3	159	76	44	21	15	♂	V.
52	238	209	110	52·6	118	56·4	162	77·5	45	21·5	13	♂	V.
53	237	207	106	51·2	115	55·5	157	75·8	46	22·2	15	♂	VI.
54	234	207	107	51·6	115	55·5	155	74·1	47	22·7	14	♀	VI.
55	232	204	110	53·9	114	55·8	152	74·5	47	23	15	♂	VI.

1 mile N.E. of New Quay, November 24th, 1913. 4″ mesh.

56	272	240	127	52·9	136	56·6	185	77	52	21·6	14	♀	V.
57	270	242	124	51·2	130	53·7	179	73·9	48	19·8	14	♀	V.
58	266	235	121	51·4	129	54·9	179	76·1	48	20·4	14	♂	V.
59	265	233	118	50·6	130	55·7	179	76·8	50	21·4	15	♀	V.
60	264	236	122	51·7	130	55	178	75·4	50	21·1	14	♀	V.
61	260	229	117	51·1	127	55·4	171	74·6	48	20·9	14	♀	V.
62	256	226	119	52·6	127	56·2	173	76·5	48	21·2	15	♂	V.
63	256	225	114	50·6	127	56·4	171	76	48	21·3	13	♂	V.
64	254	227	118	51·9	123	54·1	171	75·3	45	19·8	14	♀	V.
65	254	221	116	52·4	127	57·4	172	77·8	50	22·6	15	♂	V.
66	253	220	114	51·8	123	55·9	168	76·3	48	21·8	15	♀	V.
67	251	222	114	51·3	119	53·6	168	75·6	48	21·6	15	♂	V.

Penrhyn Weir, Bangor, November 24th, 1913.

68	271	241	125	51·8	132	54·7	185	76·7	50	20·7	14	♀	V.
69	271	239	123	51·4	130	54·3	181	75·7	48	20·1	16	♀	V.
70	260	229	124	54·1	127	55·4	175	76·4	51	22·3	14	♂	V.
71	259	229	115	50·2	122	53·2	172	75·1	48	20·9	14	♀	V.
72	256	226	117	51·7	124	54·8	174	76·9	49	21·6	15	♀	V.
73	250	221	118	53·3	124	56·1	168	76	49	22·1	14	♂	V.
74	248	217	114	52·5	122	56·2	167	76·9	48	22·1	13	♀	V.
75	246	217	114	52·5	121	55·7	166	76·5	48	22·1	14	♂	VI.
76	241	214	112	52·3	118	55·1	157	73·3	46	21·5	14	♂	V.
77	219	197	98	49·7	105	53·3	144	73·1	43	21·8	14	♂	V.
78	218	185	94	50·8	102	55·1	138	74·5	39	21	14	♀	I.-II.
79	203	177	99	55·9	101	57	134	75·7	41	23·1	13	♀	I.-II.
80	202	179	94	52·5	99	55·3	137	76·5	42	23·4	14	♂	I.-II.

½ mile from New Quay Head, December 8th, 1913. 4″ mesh.

81	282	252	130	51·5	145	57·5	190	75·4	53	21	16	♀	V.
82	275	244	126	51·6	134	54·9	182	74·5	51	20·9	14	♀	V.
83	267	240	124	51·6	133	55·4	181	75·4	49	20·4	14	♀	V.
84	266	236	119	50·4	133	56·3	181	76·6	50	21·1	15	♀	V.
85	266	234	120	51·3	130	55·5	175	74·7	49	20·9	14	♂	V.
86	264	235	121	51·4	130	55·3	179	76·1	50	21·2	16	♂	V.
87	258	229	119	51·9	129	56·3	173	75·5	50	21·8	14	♂	V.
88	254	224	117	52·2	127	56·7	171	76·3	47	20·9	14	♂	V.
89	252	221	119	53·8	125	56·5	174	78·7	48	21·7	14	♂	V.
90	250	223	117	52·4	123	55	172	77·1	47	21	15	♂	V.
91	249	221	116	52·4	124	56·1	171	77·3	47	21·2	15	♂	V.
92	243	213	109	51·1	118	55·4	162	76	48	22·5	15	♀	V.

Moelfre, December 8th, 1913.

93	254	224	115	51·3	123	54·9	170	75·8	50	22·3	13	♂	VI.
94	253	224	116	51·7	123	54·9	170	75·8	48	21·4	13	♂	VI.
95	253	223	114	51·1	122	54·7	168	75·3	50	22·4	13	♂	V.
96	249	221	115	52	122	55·2	170	76·9	47	21·2	14	♂	VI.
97	242	213	112	52·5	119	55·8	168	78·8	45	21·1	14	♂	V.
98	241	212	111	52·3	116	54·7	162	76·4	45	21·2	13	♀	V.
99	240	211	108	51·1	116	54·9	159	75·3	45	21·3	14	♀	VI.
100	239	212	111	52·3	119	56·1	162	76·4	47	22·1	14	♀	VI.
101	239	211	107	50·7	116	54·9	159	75·3	44	20·8	13	♂	VI.
102	237	208	105	50·4	117	56·2	159	76·4	46	22·1	14	♀	VI.

Penrhyn Weir, December 9th, 1913.

103	254	226	118	52·2	124	54·8	170	75·2	48	21·2	14	♀	V.
104	254	225	116	51·5	124	55·1	170	75·5	47	20·8	14	♀	V.
105	254	222	116	52·2	122	54·9	170	76·5	50	22·5	14	♂	V.
106	252	223	115	51·5	121	54·2	165	73·9	49	21·9	14	♀	II.-III.
107	238	211	107	50·7	114	54	155	73·4	45	21·3	13	♂	V.
108	238	210	108	51·4	116	55·2	161	76·6	45	21·4	14	♀	V.
109	214	186	97	52·1	103	55·3	140	75·2	44	23·6	12	♀	I.-II.
110	206	181	96	53	101	55·8	136	75·1	42	23·2	14	♂	I.-II.
111	205	181	93	51·3	102	56·3	133	73·4	41	22·6	13	♀	I.-II.
112	204	183	92	50·2	98	53·5	134	73·2	41	22·4	12	♀	I.-II.
113	202	174	94	54	96	55·1	129	74·1	41	23·5	14	♀	I.-II.
114	201	174	90	51·7	97	55·7	131	75·2	40	22·9	12	♀	I.-II.
115	199	172	88	51·1	94	54·6	128	74·4	40	23·2	12	♀	I.-II.
116	198	174	88	50·5	96	55·1	130	74·7	40	22·9	14	♂	I.-II.
117	198	173	91	52·6	96	55·4	128	73·9	41	23·7	14	♂	I.-II.
118	195	174	93	53·4	97	55·7	131	75·2	41	23·5	13	♂	I.-II.
119	192	171	89	52	94	54·9	128	74·8	40	23·3	14	♂	I.-II.
120	184	161	84	52·1	88	54·6	120	74·5	38	23·6	13	♀	I.-II.

Tremadoc Bay, December 18th, 1913.

121	261	230	118	51·3	126	54·7	172	74·8	50	21·7	15	♀	VI.
122	255	227	118	51·9	123	54·1	170	74·9	47	20·7	14	♀	V.
123	255	226	115	50·8	120	53·1	166	73·4	45	19·9	15	♂	V.
124	250	222	114	51·3	117	52·7	166	74·8	45	20·2	15	♀	VI.
125	249	220	115	52·2	121	55	167	75·9	46	20·9	14	♂	VI.
126	246	218	112	51·3	121	55·5	164	75·2	47	21·5	14	♀	VI.
127	246	217	112	51·6	116	53·4	162	74·6	47	21·6	15	♀	VI.
128	245	217	111	51·1	118	54·3	164	75·5	44	20·2	15	♀	V.
129	242	218	111	50·9	117	53·6	162	74·3	45	20·6	15	♀	V.
130	241	213	110	51·6	116	54·4	157	73·7	46	21·6	13	♂	VI.
131	236	210	109	51·9	111	52·8	155	73·8	45	21·4	15	♂	VI.

Moelfre, January 6th, 1914.

132	268	236	121	51·2	129	54·6	177	75	47	19·9	14	♂	V.
133	257	231	119	51·5	127	54·9	174	75·3	49	21·2	14	♀	V.
134	246	220	113	51·3	122	55·4	170	77·2	46	20·9	15	♂	VI.
135	245	215	112	52·1	118	54·8	163	75·8	48	22·3	13	♂	VI.
136	244	214	107	50	116	54·2	160	74·7	46	21·5	13	♂	VI.
137	243	214	112	52·3	119	55·6	162	75·7	47	21·9	14	♀	VI.
138	238	212	108	50·9	116	54·7	159	75	45	21·2	13	♂	VI.
139	233	204	103	50·5	113	55·4	155	75·9	44	21·5	13	♀	VI.
140	223	197	103	52·2	110	55·8	149	75·6	45	22·8	13	♂	VI.-I.
141	222	197	101	51·2	109	55·3	146	74·1	44	22·3	13	♀	VI.-I.
142	222	193	101	52·3	105	54·4	145	75·1	43	22·2	14	♂	VI.-I.
Mean				51·74		55·22		75·76		21·58	14·03		

Table II.

150 Herring: trawled off The Smalls about October 25th, 1913.

			D		V		A		l.cp.l.				
No.	T	T.cd.		% T.cd.		% T.cd.		% T.cd.		% T.cd.	K_2	s.	g.
1	311	280	147	52·5	153	54·6	209	74·6	59	21·1	14	♂	V.
2	309	272	144	52·9	152	55·8	207	76·1	58	21·3	14	♂	V.
3	301	262	139	53	149	56·8	200	76·3	61	23·3	13	♀	V.
4	300	262	134	51·1	147	56·1	199	75·9	58	22·2	13	♀	V.
5	298	260	141	54·2	149	57·3	200	76·9	61	23·4	13	♂	V.
6	292	255	136	53·3	141	55·3	195	76·4	57	22·3	13	♀	V.
7	292	256	140	54·6	143	55·8	198	77·3	59	23	14	♀	V.
8	292	255	140	54·9	148	58	196	76·8	58	22·7	14	♀	V.
9	292	257	139	54	148	57·5	198	77	57	22·2	13	♂	V.
10	292	257	139	54	144	56	198	77	57	22·2	15	♂	V.
11	291	252	132	52·3	140	55·5	192	76·1	59	23·4	13	♀	V.
12	290	257	136	52·9	142	55·2	192	74·7	55	21·4	13	♂	V.
13	290	257	136	52·9	144	56	196	76·2	56	21·8	15	♀	V.
14	288	252	136	53·9	141	55·9	189	75	54	21·4	14	♀	V.
15	288	250	130	52	139	55·6	191	76·4	58	23·2	14	♂	V.
16	288	256	136	53·1	143	55·8	196	76·5	57	22·2	14	♂	V.
17	287	251	131	52·1	142	56·5	190	75·6	55	21·9	13	♀	V.
18	287	252	130	51·5	138	54·7	189	75	54	21·4	14	♂	V.
19	285	248	125	50·4	136	54·8	188	75·8	53	21·3	14	♂	V.
20	285	254	133	52·3	144	56·6	191	75·2	56	22	13	♂	V.
21	284	250	136	54·4	139	55·6	188	75·2	58	23·2	13	♂	V.
22	284	249	130	52·2	141	56·6	191	76·7	55	22·1	14	♂	V.
23	284	249	132	53	137	55	189	75·9	55	22·1	14	♂	V.
24	283	251	135	53·7	137	54·5	185	73·7	53	21·1	14	♀	V.
25	282	244	132	54·1	138	56·5	189	77·4	54	22·1	14	♀	V.
26	282	253	133	52·5	141	55·7	194	76·6	57	22·5	15	♀	V.
27	282	252	135	53·5	141	55·9	195	77·3	60	23·8	15	♂	V.
28	281	250	132	52·8	139	55·6	188	75·2	57	22·8	14	♀	V.
29	280	243	127	52·2	138	56·7	188	77·3	53	21·8	14	♂	V.
30	280	249	138	55·4	141	56·6	193	77·5	58	23·3	14	♀	V.
31	280	248	132	53·2	137	55·2	191	77	57	23	15	♂	V.
32	280	245	131	53·4	138	56·3	192	78·3	55	22·5	14	♂	V.
33	279	242	130	53·7	136	56·2	183	75·6	53	21·8	14	♀	V.
34	278	244	124	50·8	139	56·9	187	76·6	53	21·7	14	♂	V.
35	277	245	131	53·4	134	54·6	183	74·6	57	23·2	14	♀	V.
36	277	246	129	52·4	134	54·4	181	73·5	55	22·4	15	♀	V.
37	277	245	130	53	136	55·5	189	77·1	54	22·1	14	♂	V.
38	277	245	130	53	139	56·7	191	77·9	55	22·4	15	♀	V.

Table II.—*continued.*

			D.		V.		A.		l.cp.l.				
No.	T.	T.cd.		% T.cd.		% T.cd.		% T.cd.		% T.cd.	K_2	s.	g.
39	277	245	130	53	137	55·9	189	77·1	52	21·2	14	♂	V.
40	277	241	128	53·1	135	56	182	75·5	53	22	14	♂	V.
41	277	245	131	53·4	135	55·1	188	76·7	56	22·8	14	♂	V.
42	277	246	132	53·6	138	56·1	186	75·6	53	21·5	14	♀	V.
43	277	245	130	53	139	56·7	187	76·3	56	22·8	14	♂	V.
44	276	240	127	52·9	134	55·8	184	76·6	56	23·3	12	♂	V.
45	276	240	127	52·9	134	55·8	183	76·3	55	22·9	15	♀	V.
46	276	244	127	52	132	54·1	184	75·4	48	19·7	14	♀	V.
47	275	241	127	52·7	133	55·1	180	74·6	54	22·4	14	♀	V.
48	275	240	128	53·3	139	57·9	187	77·9	54	22·5	14	♂	V.
49	275	243	127	52·2	133	54·7	183	75·3	52	21·3	14	♀	V.
50	275	242	130	53·7	133	54·9	184	76	56	23·2	14	♂	V.
51	275	244	125	51·2	130	53·2	186	76·2	54	22·1	14	♀	V.
52	275	242	130	53·7	133	54·9	187	77·2	53	21·9	15	♀	V.
53	275	243	125	51·4	132	54·3	183	75·3	54	22·2	13	♂	V.
54	274	245	134	54·7	141	57·5	190	77·5	57	23·3	13	♂	V.
55	273	239	127	53·1	136	56·9	183	76·5	52	21·7	14	♂	V.
56	273	241	126	52·2	137	56·8	183	76·1	57	23·7	14	♀	V.
57	273	243	127	52·2	136	55·9	185	76·1	55	22·6	14	♂	V.
58	273	243	124	51	134	55·1	185	76·1	52	21·4	14	♂	V.
59	272	239	128	53·5	135	56·4	184	76·9	52	21·7	15	♀	V.
60	272	241	128	53·1	132	54·7	181	75·1	56	23·2	15	♂	V.
61	272	236	125	52·9	134	56·7	179	75·8	52	22	14	♀	V.
62	272	244	127	52	136	55·7	184	75·4	52	21·3	14	♀	V.
63	272	241	124	51·4	135	56	186	77·1	55	22·8	14	♂	V.
64	272	242	125	51·6	133	54·9	182	75·2	52	21·5	14	♂	V.
65	272	239	126	52·7	134	56	182	76·1	55	23	14	♂	V.
66	272	242	129	53·3	138	57	187	77·2	54	22·3	14	♂	V.
67	270	237	127	53·5	132	55·7	181	76·3	52	21·9	13	♀	V.
68	270	236	124	52·5	131	55·5	181	76·7	49	20·7	15	♀	V.
69	270	240	129	53·7	133	55·4	183	76·3	54	22·5	14	♀	V.
70	269	236	126	53·4	131	55·5	182	77·1	52	22	14	♀	V.
71	268	236	125	52·9	133	56·3	182	77·1	49	20·7	14	♂	V.
72	268	236	125	52·9	131	55·5	176	74·5	53	22·5	14	♀	V.
73	268	237	128	54	131	55·2	182	76·7	56	23·6	15	♀	V.
74	267	233	122	52·3	131	56·2	177	75·9	49	21	13	♂	V.
75	267	235	127	54	135	57·4	180	76·6	55	23·4	13	♂	V.
76	267	236	126	53·4	133	56·3	180	76·2	53	22·5	14	♂	V.
77	266	236	124	52·5	131	55·5	179	75·8	54	22·9	13	♂	V.
78	266	235	123	52·3	131	55·7	180	76·6	52	22·1	14	♂	V.
79	265	232	121	52·1	133	57·3	179	77·1	51	22	13	♀	V.
80	265	235	125	53·2	131	55·7	180	76·6	53	22·6	15	♂	V.
81	265	235	120	51	128	54·4	170	72·3	52	22·1	15	♂	V.
82	265	237	125	52·7	134	56·5	179	75·5	55	23·2	14	♀	V.
83	265	238	125	52·5	132	55·4	184	77·2	53	22·2	14	♂	V.
84	265	230	121	52·6	126	54·7	175	76·1	51	22·1	15	♀	V.
85	264	229	123	53·7	126	55	171	74·6	49	21·4	14	♂	V.
86	264	233	122	52·3	131	56·2	177	75·9	53	22·7	15	♀	V.
87	264	229	123	53·7	130	56·7	170	74·2	54	23·6	13	♂	V.
88	264	231	125	54·1	130	56·2	179	77·4	51	22·1	14	♀	V.
89	264	235	123	52·3	131	55·7	176	74·9	51	21·7	14	♀	V.
90	263	231	123	53·2	130	56·2	172	74·4	53	22·9	13	♂	V.
91	263	232	123	53	129	55·6	178	76·7	51	22	14	♀	V.
92	263	231	121	52·3	133	57·5	177	76·6	53	22·9	13	♀	V.
93	263	233	125	53·6	127	54·5	177	75·9	53	22·7	14	♀	V.
94	263	236	128	54·2	134	56·7	181	76·7	54	22·9	12	♂	V.
95	263	225	128	54·4	131	55·7	179	76·1	53	22·5	14	♂	V.
96	262	229	124	54·1	128	55·9	169	73·8	52	22·7	13	♀	V.

Table II.—*continued.*

			D.		V.		A.		l.cp.l.				
No.	T.	T.cd.		% T.cd.		% T.cd.		% T.cd.		% T.cd.	K_2	s.	g.
97	262	231	121	52·3	132	57·1	180	77·9	51	22·1	15	♂	V.
98	262	233	123	52·7	132	56·6	178	76·4	52	22·3	14	♂	V.
99	262	232	125	53·8	129	55·6	177	76·2	50	21·6	14	♂	V.
100	261	230	126	54·7	130	56·5	179	77·8	53	23	14	♀	V.
101	261	229	120	52·4	126	55	173	75·5	51	22·3	14	♂	V.
102	261	227	117	51·5	124	54·6	173	76·2	53	23·3	13	♀	V.
103	260	226	120	53·1	124	54·8	172	76·1	53	23·4	14	♀	V.
104	260	231	124	53·6	126	54·5	175	75·7	52	22·5	15	♀	V.
105	260	231	122	52·8	129	55·8	173	74·9	52	22·5	13	♀	V.
106	259	234	125	53·4	131	55·9	181	77·3	50	21·3	14	♂	V.
107	259	229	119	51·9	130	56·5	175	76·1	50	21·8	14	♂	V.
108	259	230	120	52·1	125	54·3	173	75·2	55	23·9	14	♂	V.
109	259	229	119	51·9	125	54·5	170	74·2	50	21·8	14	♂	V.
110	256	228	120	52·6	125	54·8	172	75·4	51	22·3	13	♂	V.
111	255	220	122	55·4	126	57·2	171	77·7	50	22·7	14	♂	V.
112	255	224	118	52·6	128	57·1	170	75·8	52	23·2	14	♂	V.
113	255	224	116	52·2	122	54·9	165	74·3	50	22·5	15	♂	V.
114	255	225	119	52·8	124	55·1	169	75·1	50	22·2	15	♂	V.
115	255	230	123	53·4	128	55·6	177	76·9	52	22·6	14	♀	III.-IV.
116	255	227	121	53·3	125	55	173	76·2	50	22	14	♂	V.
117	254	234	124	52·9	130	55·5	178	76	50	21·3	14	♀	V.
118	254	228	119	52·2	125	54·8	169	74·1	48	21·1	14	♀	V.
119	254	222	120	54	124	55·8	171	77	51	22·9	15	♂	V.
120	253	224	115	51·3	121	54	172	76·7	53	23·7	14	♂	V.
121	253	225	119	52·8	125	55·5	172	76·4	48	21·3	14	♂	V.
122	251	222	117	52·7	124	55·8	170	76·5	49	22·1	13	♂	IV.-V.
123	251	223	120	53·8	128	57·4	175	78·4	48	21·5	14	♂	IV.-V.
124	249	218	113	51·8	122	55·9	165	75·6	50	22·9	13	♂	V.
125	249	222	118	53·1	122	54·9	169	76·1	49	22	14	♀	V.
126	248	217	115	52·9	119	54·8	165	76	44	20·3	14	♂	IV.-V.
127	248	224	121	54	125	55·8	171	76·3	49	21·8	15	♀	V.
128	248	218	118	54·1	122	55·9	167	76·6	50	22·9	13	♀	III.-IV.
129	248	221	114	51·5	119	53·8	166	75·1	46	20·8	13	♀	III.-IV.
130	247	222	114	51·3	122	54·9	169	76·1	49	22·1	14	♀	V.
131	245	215	114	53	118	54·8	160	74·4	48	22·3	14	♀	V.
132	245	220	113	51·3	119	54·1	166	75·4	48	21·8	14	♀	V.
133	245	215	112	52·1	117	54·4	163	75·8	45	20·9	14	♂	V.
134	244	211	112	53	117	55·4	164	77·7	45	21·3	15	♀	IV.-V.
135	244	215	112	52·1	117	54·4	161	74·8	49	22·8	14	♂	V.
136	244	217	110	50·6	115	52·9	162	74·6	48	22·1	13	♀	IV.-V.
137	244	219	118	53·8	121	55·2	165	75·3	48	23	13	♀	IV.
138	244	217	112	51·6	120	55·3	165	76	45	20·7	13	♀	V.
139	243	216	114	52·7	119	55·1	162	75	46	21·3	14	♀	V.
140	242	213	110	51·6	117	54·8	161	75·5	47	22·1	14	♂	V.
141	241	213	108	50·7	117	54·8	164	77	48	22·5	13	♂	V.
142	239	213	109	51·1	116	54·4	163	76·5	45	21·1	15	♀	IV.-V.
143	238	211	111	52·6	116	54·9	161	76·3	45	21·3	14	♂	V.
144	238	211	109	51·6	117	55·4	161	76·3	45	21·3	15	♂	V.
145	238	211	113	53·5	117	55·4	156	73·9	47	22·2	12	♂	V.
146	237	210	107	50·9	114	54·3	159	75·7	45	21·4	14	♀	V.
147	236	210	109	51·9	116	55·2	155	73·8	47	22·3	14	♂	IV.-V.
148	236	208	112	53·8	116	55·8	161	77·4	47	22·6	14	♂	IV.-V.
149	235	210	109	51·9	122	58·1	162	77·1	48	22·8	13	♂	IV.-V.
150	221	196	104	53	107	54·6	147	75	43	21·9	14	♂	I.
Mean				52·81		55·64		75·91		22·22	13·91		

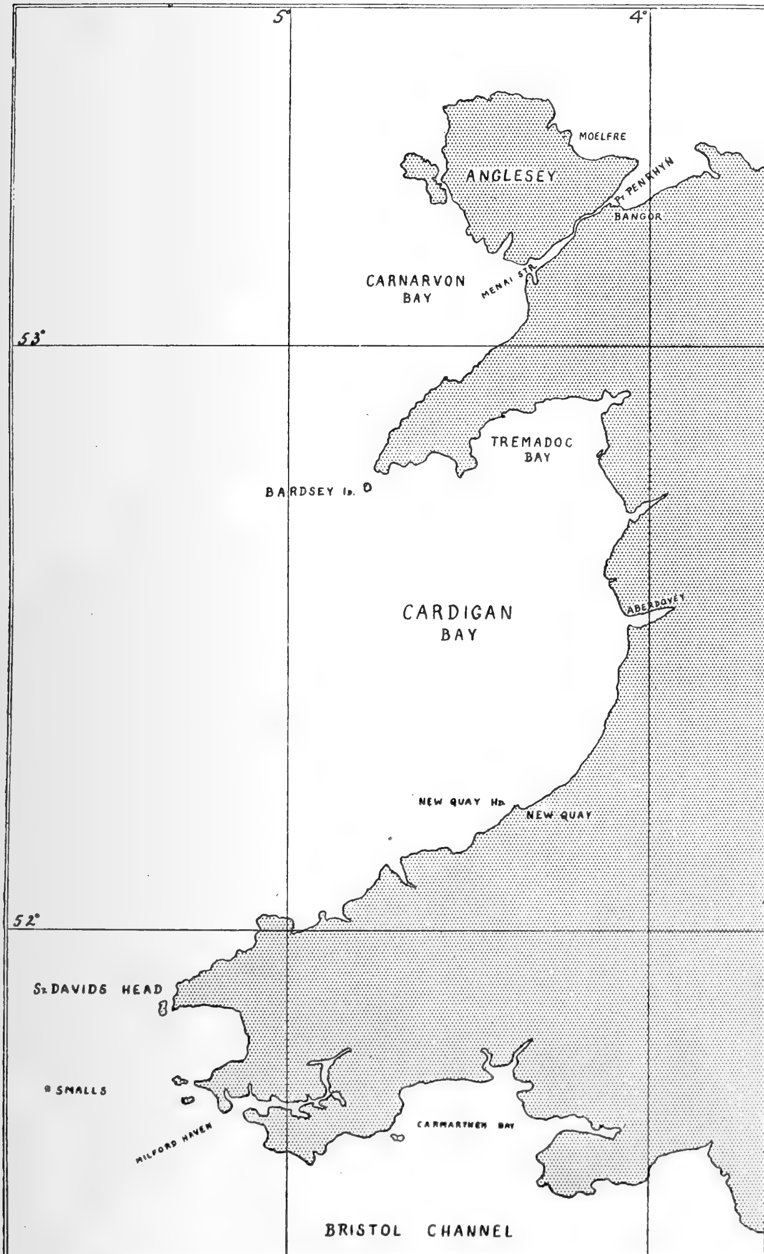


Chart of Welsh Coast showing localities sampled.

Appendix.

A New Fish-measuring Board.

At the commencement of our herring measurements we were confronted by the difficulty that there was no apparatus suitable for rapidly and accurately making measurements of fish to the nearest millimetre. None of the boards actually in use could be used to measure more accurately than to half a centimetre, and any form of calliper is slow in use, even if accurate. Another objection to callipers is that the points are often so blunt that it is difficult to adjust them sharply to the desired point upon the body of the fish.

It was to meet this need that this new board has been designed. It has been elaborated from our ideas and manufactured by Mr. Pye, Mechanician to the Physics Department in the University of Liverpool.

The actual board is of the usual pattern. Across one end is a wooden stop, against which is placed the extremity of the fish on which the measurements are to be made, the body of the fish being kept parallel to the edge of the board.

Along one edge of the board is inserted a boxwood scale, graduated in centimetres and millimetres. Parallel to this, and bracketed to the edge of the board, is a stout brass rod, square in section, running almost the whole length of the board. Along this rod travels the actual measuring apparatus. Fig. 1 shows part of the board, with the scale, rod, and measuring apparatus.

A separate view of the latter, on a larger scale, is given in fig. 2. The base of this apparatus consists of a square tube, which fits the brass rod attached to the board, and is held in position by a pair of flat springs (shown clearly in fig. 1) pressing against the rod.

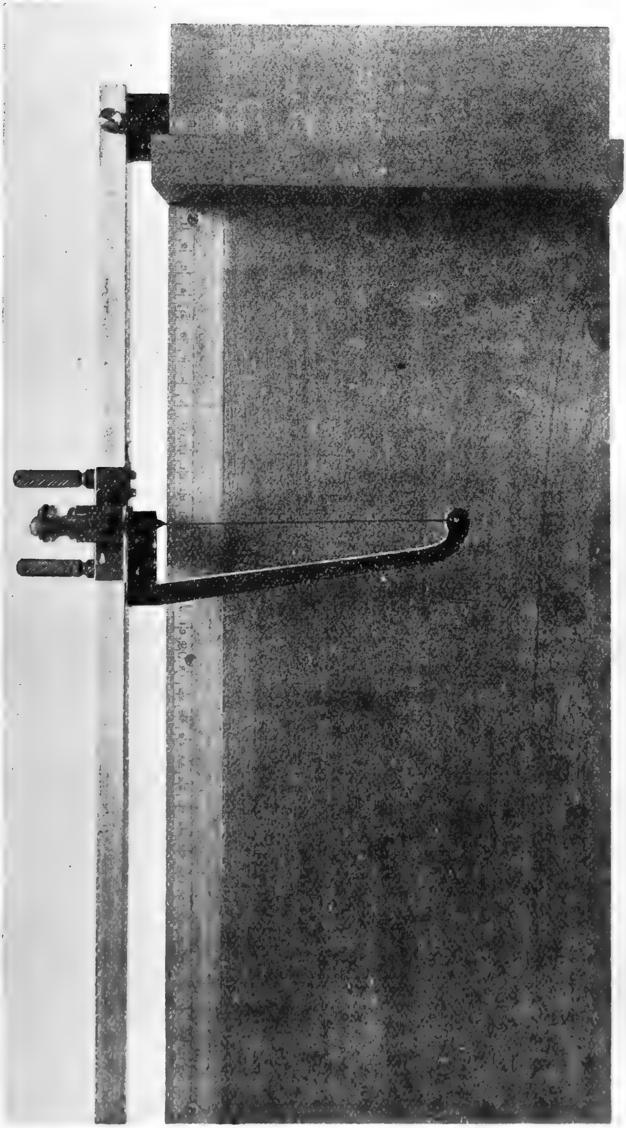


FIG. 1. Board with Measuring Apparatus in Position.

The inner surface of this tube (that next the board) has attached to it a pointer, which projects slightly over the scale on the board, being raised above it just sufficiently to allow it to travel freely without any danger of catching.

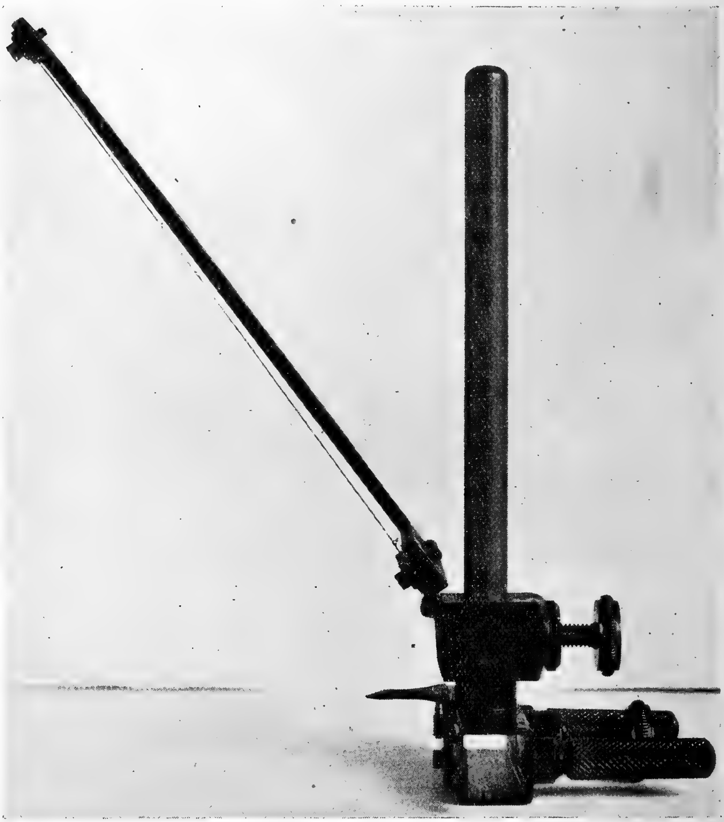


FIG. 2. Measuring Apparatus.

The outer surface is provided with a pair of pillars, forming a grip for the hand, between which is a thumbscrew by means of which the apparatus can be firmly clamped to the rod if desired.

The upper surface carries a stout brass pillar, upon which slides a square block which can be clamped in position by a thumbscrew. To the inner surface of this block is attached a curved arm, carrying a tightly-stretched wire. This arm is hinged to the block, the hinge being accurately adjusted, so that when the arm is moved up or down the wire always travels in the one plane perpendicular to the surface of the board. Owing to this hinge, and to the sliding of the block upon the pillar, this wire can be accurately adjusted to any desired position upon the body of the fish, whatever its thickness. Then one looks down upon the wire, in line with the pointer below, when the desired measurement is read off accurately upon the scale.

In actual practice we have found it desirable to set the wire by means of a line ruled across the board perpendicular to the edge of the scale. It is seldom necessary to move the block on the pillar; unless the fish vary very greatly in thickness the swinging of the arm affords all necessary clearance.

We have found this board very satisfactory, as it is both accurate and rapid in use.

REPORT ON THE EXAMINATION OF MARINE DEPOSITS IN RELATION TO THE CONTENTS OF FISHES' STOMACHS FROM THE IRISH SEA.

By Robert Ray, B.Sc.,
Lecturer in Zoology in the South African College,
Cape Town.

Introduction.

In February, 1913, I took up this line of research at the suggestion of Professor Herdman, to whom I am greatly indebted, not only for the idea itself, but also for much subsequent help and advice during the course of the investigation. This work would have been entirely beyond my reach, indeed, had it not been for his kindness in obtaining permission for me to use the Fisheries steamer, "James Fletcher," to collect the samples of bottom-deposits, gather data regarding the fauna associated with these deposits, and obtain supplies of fish-stomachs for examination in the laboratory.

The title of this paper indicates an extensive investigation, and when I took up the work it became clear that, to obtain sufficient data for satisfactory conclusions, a considerable period of time would be required. I therefore drew up a course of work to cover at least two years, from which I hoped to gather sufficient evidence regarding the types of food consumed by the various food-fishes at different seasons of the year, and the movements of the fauna on the sea-bottom, to draw conclusions of a trustworthy and possibly important nature regarding the feeding-migrations of fishes. In pursuance of this plan I began, after the Easter vacation, the collection of fish-stomachs from the various fishing-grounds of the Irish Sea, and made a detailed examination of their contents in the

Zoological Laboratory at Liverpool University, intending to continue this portion of the work mainly until November, in order to gather a large amount of data regarding the actual food of the fishes before beginning the more detailed study of the bottom-deposits and the fauna found burrowing in and associated with these. Up to now, I have examined the stomachs of over 1,600 fish, but have done little to the deposits beyond collecting and preserving them and noting their general characters. This report can, then, only be looked upon as a preliminary account of the research, which would not have been published at this time were it not that I have had to give up this work in Liverpool on receiving an appointment in the University at Cape Town. It is in the hope that some future investigator in Liverpool will take up and complete this work that I think it desirable to make available the following record of what I have been enabled to do under the peculiarly advantageous circumstances, which obtain in the University of Liverpool, for the successful pursuit of marine biological investigation.

Previous Records.

Before proceeding to the results of my own work it may be well to refer, briefly, to similar work which has been done in the past, and especially to that carried on by the naturalists of the Liverpool Marine Biology Committee and of the Lancashire and Western Sea Fisheries Committee in the Irish Sea.

Much important work has been done in connection with the food-fishes, their food, and the fauna in general associated with certain fishing grounds around our coasts by many distinguished naturalists, such as the carefully prepared reports drawn up by Professor McIntosh in his book "The Resources of the Sea" (1899), in which investigations of the greatest value to the Fisheries of Scotland are described and the results tabulated. It is probable, however, that dealing as I am with

the food-fishes of the Irish Sea, local conditions will be found to play a great part, and consequently I need only refer, at this stage, to work already done in the Irish Sea area. In the report, by Professor Herdman, on the work of the Sea Fisheries Laboratory* for 1892 and 1893 we find the first reference regarding local investigations on the food of fishes. These researches were carried on for four years, and a total of about 6,000 food-fishes were examined. These varied in size from about 4 in. upwards, and were taken from many points in that part of the Irish Sea lying between the Isle of Man and the Lancashire and Cumberland coasts. Much valuable information as to the general type of food consumed by the various kinds of food-fishes was obtained, but at that time no data were obtained regarding the food of fishes in the Western or Welsh District. Now, however, that the Fisheries district extends down the Welsh coast to Newquay, a more general survey of the whole of the Eastern half of the Irish Sea is rendered possible.

During the researches carried on between 1892 and 1896 many young fishes, especially plaice, dabs and soles, ranging in size from an inch upwards, were also examined, and this, I consider, is quite as important a part of the work as the examination of the stomachs of the more mature individuals. Unfortunately I have not had the time to carry out fully my original programme, which included the examination of these young fish.

The general conclusions come to by Professor Herdman and his assistants, during their work on this subject, was that within certain limits certain fish fed for the most part on the same type of food, and that when this was not so, as occasionally happened, the reason was to be found in the fact that the particular kind of food usually eaten by these fish was tem-

* *Trans. Liverpool Biol. Soc.*, vols. VII and VIII.

porarily scarce, or that the organisms forming the unusual food were, for the time, very abundant. It is also suggested that the movements of fish in the Irish Sea may be accounted for, to a certain degree at any rate, by the movements or migrations of their food.

The second part of my work, which includes the examination and general distribution of the bottom-deposits of the Irish Sea, has also been touched on, to some extent, by previous observers. In the Eighth Annual Report of the Liverpool Marine Biology Committee (1894–95), Professor Herdman gave a preliminary account of the submarine deposits of the Irish Sea. In this report a general outline was given of the contour of the bottom of that part of the Irish Sea lying between the Isle of Man and England. It was found that the Isle of Man and Lancashire were connected by a plateau, which except at a few places was never more than 14-16 fathoms below the surface of the sea. The surface of this plateau consisted for the most part of sand (siliceous) out to a depth of 10 fathoms, but further out, between the 10 and 20 fathom line, this sand was mixed to a certain extent with mud, and was much diversified by gravelly and shelly patches, while local muddy tracts, due to eddies and currents, were not uncommon. The effect of certain types of deposits upon the distribution of the bottom fauna was also discussed, and it was found that undoubtedly the fauna varied from place to place with the nature of the sea-floor. Samples of the bottom were sent, at Sir Archibald Geikie's request, to the museum of the Geological Survey in London, and the report of the Geological expert (Mr. Clement Reid) upon the origin of these deposits is contained in this and in the Ninth Annual Report of the L.M.B.C. (1895-96).

In this Ninth Report the second article on the Submarine Deposits is chiefly devoted to giving reasons for modifying the "Challenger" classification of submarine deposits (Terrigenous

and Pelagic), so as adequately to represent the conditions obtaining in shallow waters like the Irish Sea. The classification proposed is as follows :—

1. Terrigenous (Murray's term restricted)—where the deposit is formed chiefly (say, at least two-thirds, 66 %) of mineral particles derived from the waste of the land.
2. Neritic—where the deposit is largely of organic origin, its calcareous matter being derived from the shells and other hard parts of the animals and plants living on the bottom.
3. Planktonic—(Murray's Pelagic)—where the greater part of the deposit is formed of the remains of free-swimming animals and plants which lived in the sea above the deposit.

It is evident that some such classification as the above was very necessary. Murray's term "terrigenous" was coined to represent those deposits which were formed from the wastage and weathering of adjoining land-surfaces. In the Irish Sea, however, where, from their position, the deposits ought all to be terrigenous, many are found to contain as little as 17 % of Silica, and are formed of the remains of bottom-living animals. Such deposits as these, examples of which are the Nullipore and Shelly bottoms, so common in certain areas, could not possibly, it is evident, be classified under the term "terrigenous" and, therefore, the new division was found necessary, and has been adopted.

In the Proceedings of the Liverpool Geological Society for the year 1897-98, a most interesting and comprehensive paper is contributed by Herdman and Lomas, on the "Floor Deposits of the Irish Sea." In this paper it is shown how the deposits covering the bottom of the Irish Sea have been the result of (1) the denudation of the coasts, (2) the redistribution of the older deposits under the sea, and (3) vital agencies—the

remains of plants and animals living in the sea. Many deposits are analysed in a most detailed manner, but as the great majority of them were obtained from the West of the Isle of Man, or in the vicinity of that island, their work and mine do not overlap to any extent.

Finally, I might just refer to the most interesting and important work on bottom-deposits, recently published by C. G. Joh. Petersen and P. Boyson Jensen, in the Report of the Danish Biological Station, Copenhagen, for the year 1911. In this paper the sources of the organic matter in the sea, and in the sea-water, are fully discussed, as well as the deposits of organic matter on the sea bottom. Many new methods have been adopted, with great success, in their investigation, and some of them will, no doubt, be made use of in future researches of this type in the Irish Sea.

Bottom Deposits.

The samples which I have been able to collect and examine were all obtained in the portion of the Irish Sea lying North of Wales and between the Isle of Man and England. They are as follows :—

I. [1a.] 18/2/13. 25 miles W.N.W. of Piel Gas Buoy.

This deposit consists, for the most part, of small stones, very fine quartz sand, and comminuted molluscan shells. On the whole it is fairly coarse. The stones vary greatly in size—ranging from the most minute particle up to one weighing 2·4 grms. They are all well-rounded and smoothed, and the larger ones are encrusted with polyzoa and serpulids. A rough idea of the proportion of stones in the sample may be obtained from the statement that out of a total weight of 27·723 grms. the stones accounted for 10 grms. The composition of these stones varies so much that it is impossible to suggest with any accuracy their origin. Pieces of pure quartz are found along-

side chips of metamorphic rocks and schists, but these are all so small and weathered that it is impossible to obtain a fresh surface and thus gain a clue to their true identity.

Shells and pieces of shells form a very large proportion of the deposit. Excluding the stones, fully 35 % to 40 % of the remainder of the sample consists of the remains of molluscs—from complete valves down to the merest speck. Most of the genera obtained while trawling over this part of the Irish Sea are represented in this deposit. *Pecten* (many), *Cardium*, *Tellina*, *Nucula*, *Trochus*, *Arca*, *Leda*, *Emarginula*, &c., form the bulk of the unbroken shells, it being impossible to identify the smaller particles with any degree of accuracy. A feature of these smaller shell-fragments is that, almost without exception, their edges and corners are well smoothed and rounded, showing that after the original shells have been *broken* into pieces of a certain size (probably during their passage through the alimentary canals of fishes and birds), further comminution does not take place. Other organic remains found were pieces of echinoid spines, parts of echinoid shells, polyzoa, and a few *Echinocyamus pusillus*.

The true sand of the deposit consists of more or less rounded and very minute grains of pure quartz. The varieties represented are those known as milky quartz and clear quartz or rock crystal. Mingled with the quartz grains are many minute specks of magnetite and mica (muscovite). The latter must be distinguished carefully from the microscopic pieces of the nacreous layer of molluscs which are very abundant. These quartz grains make up the larger part of the deposit.

Animal life was remarkably scarce in this sample, but I think this may be due to the fact that it was obtained by means of a dredge, which I had rigged up until a Lucas Grab could be obtained. Doubtless when samples taken by the Lucas Grab or by Petersen's "Sampler" are examined the animal life will be found to be more abundant.

A few very small amphipods and some minute annelids comprised the total found in this present sample.

II. [1b.] 18/2/13. 25 miles W.N.W. of Piel Gas Buoy.

An examination of this deposit was made on similar lines to that followed in I. On the whole the two are very much the same, both in appearance and constitution. This sample was procured on the same date as I, at a point about half a mile further South. The small stones and shells form, as in the previous case, the characteristic constituents, although the proportion of the former is slightly higher than in the first case. All the representatives of the mollusca found in I were present in this sample also, with the addition of the following genera :—*Dentalium*, *Pectunculus*, and *Astarte*. The shells are, I should say, in the same proportion as those in I, but there are more larger pieces and unbroken valves than in the first sample.

The quartz sand is present as before. Echinoid spines and pieces of shell, as well as a few zoophytes, polyzoa, and annelid setae, were also found.

III. [16a and 16b.] 17/4/13. 25 miles W.N.W. of Piel Gas Buoy.

Two more samples were taken at this station on the 17th of April—one before trawling, the other after the net had been hauled, so that the positions of the samples were separated by a considerable distance. The examination serves as confirmation of the fact that for a considerable area at this part of the Irish Sea, known to trawl-fishermen as the "Hole," the conditions obtaining at the bottom are fairly uniform. A comparison of these samples with those obtained on the 18th February shows that there is little or no difference in their composition. Small stones, shells, and quartz sand predominate, and the various molluscan genera are practically identical. The following genera were identified in the present

samples :—*Pecten*, *Cardium*, *Nucula*, *Emarginula*, *Trochus*, *Dentalium*, *Arca*, *Solen*, *Buccinum*, and one specimen of *Eulimella scillae*.

Other organic constituents are echinoid spines, polyzoa (free and encrusted on the stones), serpulid tubes on the stones, a few terebellid tubes, *Balanus*, *Echinocyamus pusillus*, and zoophytes adhering to the larger shells and stones.

A fact worthy of remark is that, although the stones, in these samples from the "Hole," have no sharp corners nor rough edges, none of them are rounded and smooth after the manner usually associated with water-worn gravel. Add to this the fact that the great majority of them are absolutely encrusted with polyzoa, serpulid tubes, zoophytes, &c., and we have proof, I think, that in this particular area the currents and tides are not sufficiently strong to affect the heavier particles of the sea-bottom ; and as many of the smallest stones support the growth of various organisms, it seems likely that at this, the deepest portion of the Eastern half of the Irish Sea (20-23 fathoms), there is practically no disturbance of the sea-floor at all.

IV. [24.] 11/6/13. 23 miles W.N.W. of Piel Gas Buoy.

In contrast to the samples obtained at the station "25 miles W.N.W. of Piel Gas Buoy," which were fairly coarse, this sample obtained only two miles away is very different. It is almost wholly composed of a very fine quartz sand in which minute pieces of some delicate molluscan shells are disseminated—probably some species of *Solen* or *Tellina*.

This sand, as seen under the microscope, consists of very angular quartz grains for the most part, though a small proportion of rounded particles are also present. Magnetite is common in small specks. Many echinoid spines, a few annelid setae, and one or two "turnings" of polychaets were also found. Two samples were taken at this station on the above

date and were identical in every way. In general appearance they would be at once termed "fine clean quartz sands," but on shaking up in water it is found that a small quantity of very fine mud is spread throughout. In fact, it seems to be comparatively rarely that a "clean" sand is found in this North-eastern area of the Irish Sea.

V. [8.] 25/2/13. 20 miles N.W. ½ N. of Piel Gas Buoy.

A very small sample was procured at this station. It consists of a bluish-black, evil-smelling mud. Under the microscope this mud is seen to be composed of very minute particles of quartz, along with an enormous proportion of extremely fine matter, which appears to be of undoubted organic origin. Carbol-gentian violet gives a distinct reaction. Besides the minute quartz grains there are a number of particles, white in colour, which seem to be the remains of fine molluscan shells.

This mud is probably only local and due to a slight depression in the sea-floor, but more samples would require to be taken in the vicinity to determine this point.

VI. [2.] 18/2/13. Near Bahama Ship.

Two samples from this station have been obtained. The first, taken on 18th February, was obtained quite close to the South of the Light-ship; the second was taken about 200 yards further South on the 16th of April. A glance at these deposits shows how the sea-bottom may vary, even within very small areas, and proves the difficulty of trying to map out, with any attempt at accuracy, the floor of the Irish Sea.

Taking the first sample, it is found to consist almost entirely of pure quartz sand. The quartz grains are, for the most part, well rounded and worn, although fairly angular

particles, showing the characteristic conchoidal fracture, are by no means uncommon. The presence of oxides of iron is evident from the yellowish-red appearance of the deposit.

Besides the quartz other minerals are represented to a small extent. Grains of magnetite are sparsely spread throughout the sample. Many of the grains of quartz have a distinctly greenish tinge, and this is probably due to chlorite, formed by the alteration of former furo-magnesian constituents of the original rock, from which the deposit has been formed. A few very minute chips of stone also are scattered throughout the deposit.

Organic matter is remarkable for its absence. After carefully searching the sample all I found was a few pieces of broken shells (*Pecten* and *Tellina*), one or two echinoid spines, and one small piece of a coral. On one of the larger pieces of shell an encrusting polyzoan was found.

VII. [15.] 16/4/13 Near Bahama Ship.

Turning to the second sample, a very different state of affairs is found. It consists entirely of stones, broken shells, and quartz sand, and, in general, resembles the deposits from the "Hole." On examination, however, it is seen to differ in many important respects. Firstly, the proportions of stones, shells, and sand are different. In this deposit the most striking fact is the preponderance of stones, and especially small stones, over the other two main constituents. They vary from 4·2 grms. in weight downwards, but the great majority are of uniform dimensions and small. They are well-rounded and water-worn, and evidently are subjected to a considerable amount of grinding as in not a single instance are growths (such as polyzoa) found upon the surface, this being in striking contrast with those got at the "Hole." This is probably accounted for by the difference in depth, which at the "Hole" was 22 fathoms and at the Bahama ship only 7 fathoms.

When the shells are examined the same evidence of motion and consequent grinding on the sea-bottom is forthcoming. Not a single unbroken example was obtained, and all were so worn that the identification of even the larger fragments was a matter of great difficulty and uncertainty. Those recognised were fragments of the following genera:—*Trochus*, *Tellina*, *Mactra*, *Pecten* and *Nucula*. The fragments of shells in this deposit are much smaller than those obtained from the "Hole," and do not by any means form such a large proportion of the total.

The quartz sand is, on the whole, coarser than that obtained at the "Hole." The individual grains are much larger and, if anything, more rounded, although the proportion of broken pieces showing conchoidal fracture is higher.

Animal remains are scarce, a few echinoid spines and one small crab (*Carcinus*) constituting the total.

As will be seen it is quite impossible to draw any comparison between these two samples obtained from the vicinity of the Bahama Ship. Before that could be done, and before any definite conclusions could be arrived at, a much larger number of samples would need to be taken. It seems to me, however, highly probable that as the general type of deposit over that part of the Irish Sea, between the Isle of Man and England, is one consisting, for the most part, of almost pure quartz sand, it is more than likely that the sample taken at the Bahama Ship in April represents only a local bank of stones and shells, and that the sample of February 18th indicates more correctly the true condition of the bottom.

VIII. [3.] 18/2/13. Between Bahama Ship and the "Hole."

This sample was taken somewhat to the North of the mid-way point between the Bahama Ship and the "Hole." It consists mainly of small stones, shells, and sand (quartz). The stones are smaller and much fewer in number than in the

preceding cases, and they are absolutely free from encrusting matter of any kind. They are all well-rounded, smooth, and polished, and their composition is very varied. Before the origin of these stones can be ascertained, much purely geological work still requires to be done.

The shells and comminuted particles are numerous, although the bulk of this deposit is made up of quartz sand. There are very few complete valves, the majority being ground down to form a fine calcareous sand. The genera identified are as follows :—*Nucula*, *Cardium*, *Tellina*, *Trochus*, *Emarginula*, *Venus*, *Turritella*, and *Cerithium*.

The quartz sand, which composes by far the greater part of the deposit, is formed of the varieties rock crystal and milky quartz. The grains are all more or less rounded, but many of them are fairly angular.

Other organic remains in the sample are echinoid spines and pieces of the test, and many polyzoa.

IX. [17.] 17/4/13. Half-way between Bahama Ship and the "Hole."

The sample obtained from this station is a very coarse one, composed of small pebbles, quartz grains, and organic débris (shells). The greater part of the deposit is made up of shells which, although mostly broken, are in large pieces, constituting a very coarse sand. There is also a large proportion of finely comminuted matter. The genera identified are as follows :—*Pecten*, *Buccinum*, *Leda*, *Pectunculus*, *Nucula*, *Cardium*, *Tellina*, *Solen*, *Balanus*, and *Eulimella*. Among the other organic remains were found the spines of echinoids, comminuted particles of the rays of ophiuroids, and several specimens of *Echinocyamus pusillus*. There is no suggestion of mud or any finely reduced matter, such as is sometimes found mixed with these coarse deposits.

The quartz grains are composed, for the most part, of rock crystal and are decidedly angular in appearance, although their edges and corners have been smoothed off. Grains of magnetite or titanoferrite are common, and there are a few pieces of what I take to be hornblende as well.

The pebbles, which are by no means uncommon, are well polished and water-worn, but as several of them have polyzoan growths on their surfaces it is unlikely that they have undergone much erosion since being deposited in their present position.

X. [4 and 13.] 18/2/13 and 16/4/13. Half-way between Bahama Ship and Selker Ship.

Here we find a deposit of a totally different nature from any hitherto examined. Two samples were obtained from this station, one on February 18th, the other on April 16th. Both seem to be identical and consequently will be considered together.

These deposits consist of a bluish-grey mud which possesses a peculiarly disagreeable and penetrating odour. When first obtained it is plastic and very sticky, but after standing for a week or two in concentrated formol it assumes the consistency of a stiff clay. On examination under the microscope it appears to be made up, for the most part, of grains of quartz of the most minute size as well as diminutive particles of matter evidently of organic origin. The quartz grains vary considerably in size, even in this extraordinarily fine state of comminution. Some are easily distinguishable under the microscope, but the majority are so minute as just to be recognisable and no more. Among the organic constituents were annelid setae, small echinoid spines, the comminuted remains of minute ophiuroid rays, and many particles of zoophytes—all of which might be carried long distances by currents and tides in a state of suspension in the water.

As no haul was ever taken with the trawl over this particular area during my cruises, I cannot say what the fauna living on this deposit may be, but, judging from that obtained on the mud-banks off Duddon, it would not be prolific. Although many slides of this mud were examined, no living organism was found in it, but this does not, by any means, prove that it is destitute of life, the negative result which I obtained being probably the result of the dredge giving me a sample of the surface mud only, and I have little doubt that a sample obtained by means of the Lucas Grab would demonstrate the presence of a characteristic fauna.

The questions now naturally arise—where does this mud come from, and why is it deposited in this particular place, which is surrounded on all sides by the characteristic sand and shell deposits of the North-eastern half of the Irish Sea ?

In all probability the explanation is to be found in the fact that the general direction of the currents in the Irish Sea is from South to North. Consequently all the minute and easily transported matter brought down by the rivers Mersey and Dee, besides the numerous other smaller streams, is carried in a state of suspension in a Northerly direction, and therefore, wherever there is a slight depression in the sea-floor, sufficient to cause an eddy, this fine mud is thrown down, and so accumulates to form a deposit, such as is found between the Bahama and Selker ships. Two such depressions exist in the area from which these samples were obtained—one on either side of a line drawn from the Bahama to the Selker ships. My samples were taken at a point practically on the Southern lip of the Northern depression, at a depth of about 14 fathoms.

The peculiar and distinctive odour of this mud is caused by the quantities of decomposing organic matter found in the deposit. I made several smears of the mud, and tested for bacteria by staining with carbol-gentian violet. The result

proved, without the shadow of a doubt, that the deposit was literally swarming with bacterial organisms. I had intended testing for cellulose with chlor-zinc-iodine, and for pectoses by ruthenium-red, but, owing to lack of time, I have not been able to do so.

XI. [6.] 24/2/13. Duddon Bank.

This sample was obtained from Duddon Bank, from a depth of between 7 and 8 fathoms. It consists almost entirely of quartz sand, throughout which are scattered a few broken fragments of molluscan shells. When examined under the microscope, the quartz grains are found to be fairly well water-worn, although the majority have a decidedly angular form. They are composed almost wholly of the variety rock crystal, and are in most cases stained a yellowish-red by oxide of iron.

This is decidedly the purest deposit of quartz sand obtained so far. The quantity of shells, &c., in it is negligible as compared with the total bulk. These shells consist, for the most part, of the comminuted valves of *Tellina*, but other molluscs obtained were *Nucula*, *Venus*, *Solen* and *Scrobicularia*.

In this deposit I also found a large *Turritella* containing a small *Eupagurus*. Several legs of hermit-crabs, a very few echinoid spines, and part of one sabellid tube were also found. This sample was obtained before trawling operations were begun, and as our course while trawling was West, we soon left the bank behind and came on to the muddy area which is described in the next sample.

XII. [7.] 24/2/13. 10 miles W. of Duddon Buoy.

The sample obtained from this station proves, on examination, to be practically identical with that from half-way between Bahama Ship and Selker Ship (see X above).

The general appearance, colour, smell, and constitution agree in every respect. The mud is composed of minute

particles of quartz and organic matter of various kinds, too small for identification. The latter appears, if anything, to be more abundant in this sample than in X. As before, carbol-gentian violet proves the presence of great quantities of bacterial organisms.

As to the presence of mud in this locality, it has been known for long that a belt of mud runs Northwards from off Walney Island to the village of Drigg, opposite the Selker Ship. The general run of the tides and currents in this part of the Irish Sea is from South to North. Now, the results of the experiments made some years ago by the Lancashire and Western Sea Fisheries Scientific Staff, with drift bottles, show that the majority of these bottles were returned to the laboratory from the neighbourhood of Duddon Buoy. Few drifted North of this point, although one or two did reach the Solway Firth. It would appear, therefore, that here the current, sweeping up from the South, meets the tide coming down from the North, with the result that about Duddon Buoy a "dead-water" is formed, with the consequent precipitation of the suspended matter.

I can advance one other argument to prove that along the line of this mud belt there is slack water. When a shipwreck takes place off the Mersey Bar, the fishermen say that in searching for wreckage and cargo they always make for the neighbourhood of Duddon, as the remains are invariably carried there and are sure to be found floating about over this mud belt.

XIII. [23a and 23b.] 11/6/13. 5 miles W.S.W. of Duddon Buoy.

Two samples were obtained and examined from this station. They resemble, very closely, those described from mid-way between the Bahama and Selker Ships, and from 10 miles W. of Duddon Buoy. They are composed of exactly

the same constituents, except that the smell in this case is hardly perceptible, while the proportion of larger grains of quartz is very much higher than in the previously described samples. This, of course, might be expected, as the further to the South, the stronger will be the tides coming from the South, and therefore the larger particles will be more numerous, while a decrease will be observed in the very fine suspended matter. In this sample, however, there is no perceptible decrease in the amount of fine organic matter, and consequently it is safe to say that this point is well within the belt of dead water previously mentioned.

XIV. [14.] 16/4/13. Selker Ship.

In the deposit obtained at the Selker Ship a transition is seen to be taking place from the pure mud of the Duddon area back to the typical Irish Sea deposit of quartz sand and comminuted shells.

Although a very large proportion of fine mud and organic matter is still found in this sample, the larger type of quartz grains are also common, and resemble those found in the sandy areas of the "Hole," between Bahama Ship and the "Hole."

I shook up some of this sample with water in a large glass tube for a minute, and then allowed it to settle. The quartz sand separated out immediately and settled on the bottom, but after two hours the water was still murky with very fine suspended matter, although, certainly, the greater part of the mud had, by that time, been precipitated on the top of the quartz sand.

A considerable number of pieces of shells were found in this sample, the majority of which seem to belong to the genus *Tellina*, but most of them were in such a fine state of division as to be unrecognisable. Spines of echinoids were fairly common as well as annelid setae. Two fairly large specimens of

Nereis were found in the sample—in fact, I should imagine this type of deposit to be well suited for the support of polychaets.

XV. [5 and 12.] 18/2/13. Morecambe Bay Ship.

Two samples were obtained from Morecambe Bay Lightship, but as the position varied slightly I shall describe them separately. No. 5 sample consists of an exceedingly fine quartz sand, throughout which are scattered small particles of very fine shell. The quartz grains in this case seem to be divided into two distinct types—(1) those which are rounded and apparently well water-worn, and (2) those which are angular in shape.

Many of them are tinged yellowish-red by iron oxide. Magnetite grains are common. On the whole this is a fine clean sand, much of it being excessively fine. The pieces of thin shell found in it seem to belong to the genera *Tellina* and *Solen*. Other complete valves discovered in this deposit are *Venus*, *Mactra*, and a single example of a large *Turritella*. A few echinoid spines and annelid setae are also present.

No. 12, which was obtained in the same locality, shows a gradation from the fine clean sand of No. 5 to a pure mud. In appearance it is bluish-grey, and possesses the distinctive odour already mentioned as being characteristic of the muds near Duddon. On being shaken up with water, however, in a large glass tube, it is seen that a considerable amount of fine quartz sand is present, as it settles down at once while the mud proper takes hours to precipitate, forming a layer above the sand. The sand consists of quartz grains, similar in every way to those of sample 5. The mud is composed of extremely finely-divided particles of quartz, plus a large quantity of minute organic matter giving a distinct reaction with carbol-gentian violet. In it many annelid setae are found, while a few echinoid spines and comminuted pieces of *Solen* and *Tellina*

shells are scattered throughout. On examination of this deposit several small annelids and one large *Nereis* were found.

Judging, very roughly of course, by the height of the respective layers of sand and mud which formed, after shaking up in a glass tube, the proportion of mud to sand appears to be about 5 to 1. In a wet condition this deposit is exceedingly viscous and sticky, and when dry assumes the aspect of a fine powder from which the larger quartz grains stand out distinctly.

XVI. [11.] 26/2/13. 15 miles S.W. of Morecambe Bay Ship.

This sample is a most heterogeneous one. In the first place it is composed of small stones, shells, quartz sand, and very finely-divided mud. The stones are not very common, and vary considerably in size. They are all well rounded, but, as in one or two cases growths of zoophytes are found upon their surfaces, the erosion could not have taken place since they were deposited in their present position. Comminuted shells make up a considerable proportion of the total mass, and are of all sizes from complete valves down to the minutest speck. *Tellina*, *Mactra*, *Nucula*, *Pecten*, *Venus*, and *Cardium* seem to be the commonest genera present.

The quartz grains, forming the sand, are all pretty well rounded and worn, but many angular pieces are also present. A fair number of these are coloured by iron oxide. Magnetite and small pieces of what appears to be slaty material are found—the former in fair abundance. Throughout the whole deposit a fine mud is found—in fact this sample resembles pretty closely the second deposit described from the Morecambe Bay Ship. The proportions of quartz sand and mud, however, are more nearly equal in this case. The constitution of the mud appears to be very similar to that described for previous samples.

In this deposit a great number of terebellid and sabellid

tubes were found, and the polychaets, themselves, were frequently found in the tubes and also free in the mud. One small *Galathea* was also found, as well as several small amphipods, ophiuroids, and echinoid spines.

The fauna of this sample seems to show that the sea-bottom, at this particular point, is suitable for soles, plaice, and dabs, and this expectation is partly, at any rate, confirmed on an examination of my trawling records.

XVII. [9a and 9b.] 26/2/13. 20 miles S.W. of Morecambe Bay Ship.

On arriving at this station it seems that the mud has disappeared again, for this sample consists of a beautifully clean, but very coarse deposit of small stones, shells, and sand. As the two samples obtained are identical in every way I shall describe them as one.

The stones appear to be well water-worn, but as they are covered in most cases by growths of organic matter, the erosion must have been done previous to their arrival in their present position. In some cases they support the growth of zoophytes, serpulae, and botrylloids, while a small ascidian is found in one case. The shell sand is very rough—the majority of pieces being large. Many genera are represented, those identified being:—*Nucula* (many), *Venus*, *Pecten*, *Balanus*, *Trochus*, *Cardium* (many), *Syndosmya* and *Lima*. The quartz sand consists of a mixture of rounded (or partially rounded) and angular grains, the number of the latter being in the ascendancy. Many of these are stained by iron oxide. Magnetite or titanoferrite is common. The quartz grains are, on the whole, fine.

Besides the invertebrates mentioned above as occurring on stones in the deposit, several pieces of sabellid tubes were found, while echinoid spines and branching polyzoa were common. No trace of mud is noted.

XVIII. [18.] 26/5/13. Off Blackpool (North Shore).

Several samples were examined from this station, each and all of them proving to be of the same composition. By far the greatest part of this deposit consists of pure quartz sand, the grains of which are very uniform in size. They are well polished and rounded, a large proportion of them being stained by oxide of iron. Particles of magnetite are commonly distributed throughout, as well as a few pieces of what appears to be a micaceous sandstone. The organic constituents are formed of comminuted shells of *Tellina*, *Donax*, *Scrobicularia*, and *Mactra*, but these pieces are so minute as to make identification a matter of considerable difficulty. *Echinus* spines are fairly common.

XIX. [22.] 29/5/13. 6 miles N. of Great Ormes Head.

This deposit is made up for the most part of well-rounded quartz grains. They are considerably larger, on the whole, than those of any previously described samples. A fair proportion of them are coloured by iron oxide. Magnetite is pretty common. Shell fragments and particles are common. Few of them can be recognised, but the following is a list of those identified :—*Cardium edule*, *Tellina*, *Venus*, *Mactra*, *Scrobicularia*, *Donax* and *Purpura*. Besides these shells echinoid spines are fairly common ; one small *Spatangus* was obtained, and a few worm castings. Small stones are found here and there, but they are rare. A small proportion of mud is also present, but it is hardly noticeable except as a very thin film lying on the top of the sample after the latter has been standing at rest for some time.

XX. [10.] 26/2/13. 10 miles N. of Great Ormes Head.

In passing over the four miles which lie between this station and the last one (6 miles N. of Great Ormes Head), it is evident that the area of fine sand has been left behind—at any

rate, the present sample is the coarsest that I have examined. It is composed almost wholly of small stones and large shell-fragments, and would be termed a "shelly" deposit. Few complete valves are present, but the fragments are sufficiently large and fresh in most cases to make their identification possible. The genera recognised are:—*Pecten*, *Cardium* (many), *Nucula*, *Mactra*, *Donax*, *Emarginula*, *Trochus*, *Balanus*, *Mytilus* and *Venus*.

The stones, which are numerous, are fairly uniform in size—that of a small pea—and well water-worn. No sign of any growth of any kind is seen upon their surfaces, and, as the deposit is an absolutely "clean" one, I imagine the tides and currents are pretty strong, and consequently there follows a proportional amount of erosion on the sea-bottom.

Besides shells and stones, grains of quartz are also found in fair abundance. These grains are large, composed of rock crystal, and most of them are well-rounded. They are really too large to be termed grains in the general acceptance of the term.

Branching polyzoa, small *Spatangus*, several *Echinocyamus pusillus*, tubes of *Sabellaria* and *Serpula*, as well as echinoid spines are of pretty frequent occurrence.

XXI. [21.] **29/5/13. Red Wharf Bay.**

Two samples were obtained from this station on the above date. As they are identical in every way, the same description will stand for both.

The deposit consists of a fine sand, composed of small quartz grains and finely comminuted shells. The quartz grains are mostly fairly well water-worn, but angular particles are of frequent occurrence. Many of them are coloured by iron oxide. Magnetite or titanoferrite is pretty common as black specks. The fine state of comminution of the shell fragments is due to the fact that the majority of these are

Tellina—which, of course, have very delicate valves. Other shells found in a more or less complete condition are *Mactra*, several large *Solen*, several *Mytilus*, one *Cardium edule*.

Besides quartz sand and shells, there is quite a fair amount of mud present, which is in a finely divided state and takes a long time to settle down.

Food of Fishes.

The fish I was enabled to dissect on the trawling expeditions numbered 1,610, and were obtained from 31 different hauls. As some of the localities trawled over do not correspond with any of those from which the deposits described above were obtained (both sets of samples being collected with the intention that they should form part of a much larger series, which would cover practically the whole district), it seems probable, on inspection of the tables that have been prepared, that no useful purpose would be served by publishing the detailed data obtained from each haul at this early stage of the enquiry. The data will be kept in the laboratory for the use of those who may continue this investigation in the future, but for the present only a summary of the results for each kind of fish will be printed here.

Ray (*Raia clavata*, Linn., and others).

In all, 199 fish (several species of ray), ranging in size from 8 to 84 cms. in length, were examined. They were obtained from 9 hauls at 6 different localities, ranging from Duddon, in the North of the District, down to Carnarvon Bay. All these hauls were in April, May or June.

An examination of the tabulated lists show that the chief food of the various species of ray examined is undoubtedly crustacea.

Of the 199 stomachs examined, 19 were empty, while all the others contained recognisable food. In order that the

results may be seen at a glance, I append the following list of the number of stomachs containing the various types of food :—1 zoophytes, 1 echinoid spines, 36 *Crangon*, 6 prawns, 47 *Eupagurus*, 37 *Portunus*, 5 *Hyas*, 5 *Stenorhynchus*, 15 crayfish, 12 *Carcinus*, 25 *Corystes*, 3 *Galathea*, 3 *Mysis*, 29 *Idotea*, 49 amphipoda, 30 crustacean remains, 3 *Aphrodite*, 35 *Nereis*, 11 *Nephthys*, 19 annelida (digested), 8 *Solen*, 2 *Buccinum*, 2 *Tellina*, 1 *Mactra*, 1 *Trochus*, 1 *Pecten*, 2 *Loligo media*, 6 molluscan remains, 4 *Gobius minutus*, 1 dragonets, 1 solenettes, 3 herring, 9 sand.

Skate (*Raia batis*, Linn.).

Of this species, 18 fish, from 9 to 110 cms. in length, were examined. They were obtained from 4 hauls, in April and May, at localities ranging from Duddon to Morecambe Bay.

As in the case of the ray, crustacea seem to be their chief food. The following is a synopsis of the food contained in the various stomachs :—1 empty, 11 *Crangon*, 3 prawns, 4 *Eupagurus*, 1 *Portunus*, 1 *Hyas*, 1 *Carcinus*, 1 *Gammarus*, 1 amphipoda, 2 annelida, 1 *Philine*, 3 grey gurnards, 1 plaice, 3 soles, 1 solenettes, 1 dragonets, 1 whiting, 6 fish-remains.

Yellow Gurnards (*Trigla lucerna*, Linn.).

In all, 79 fish were obtained from 4 hauls in May and one in June; one haul was in Carnarvon Bay, the rest in the North of the District. The length of the fish varied from 9 to 44 cms.

The following is the synopsis of their stomach-contents :—30 empty, 1 ophiuroids, 10 *Crangon*, 1 *Eupagurus*, 4 *Portunus*, 1 *Hyas*, 1 *Stenorhynchus*, 1 *Carcinus*, 17 *Corystes*, 2 *Galathea*, 1 *Nucula*, 1 *Solen*, 3 amphipoda, 1 *Loligo media*, 5 *Aphrodite*, 3 soles, 4 solenettes, 1 dabs, 1 plaice, 1 megrims, 2 *Ammodytes*, 14 fish-remains, 1 indistinguishable matter, 2 stones (fairly large), 1 sand.

It is obvious from a glance at the above, that crustacea and fish compose the main food of yellow gurnards.

Red Gurnards (*Trigla cuculus*, Linn.).

Three hauls in May (one from Carnarvon Bay) yielded 106 red gurnards, ranging from 10 to 44 cms. in length.

As in the case of the yellow gurnards, crustacea and fish are the main constituents of their food as shown by the following synopsis:—30 empty, 3 zoophytes, 2 *Flustra*, 4 *Aglaophenia*, 11 *Eupagurus*, 36 *Hyas*, 11 *Stenorhynchus*, 16 *Carcinus*, 26 *Portunus*, 14 *Crangon*, 3 prawns, 3 crayfish, 8 amphipoda, 4 *Galathea*, 2 *Pecten*, 3 *Gobius minutus*, 1 *Ammodytes*, 6 small stones and sand.

Plaice (*Pleuronectes platessa*, Linn.).

From 12 hauls, at 10 localities in various parts of the district, were obtained 501 plaice. They ranged from 12 to 48 cms. in length. The hauls were taken in April, May, and June.

The staple food of this fish seems to be mollusca and annelida, as can be seen from the following:—85 empty, 2 zoophytes, 40 ophiuroids, 6 *Echinus* spines, 8 heart-urchins, 2 *Eupagurus*, 5 *Crangon*, 70 amphipoda, 3 *Idotea*, 122 *Solen*, 88 *Tellina*, 25 *Scrobicularia*, 154 *Donax*, 7 *Cardium*, 15 *Mactra*, 1 *Pecten*, 6 *Philine*, 1 *Lima*, 1 *Lutraria*, 27 *Nucula*, 7 annelida (unrecognisable), 1 *Polynoë*, 59 *Nereis*, 26 *Arenicola*, 67 sabellids, 4 *Aphrodite*, 145 terebellids, 7 *Nephthys*, 1 nudibranch, 1 *Gobius minutus*, 1 fish-remains, 171 sand.

Dabs (*Pleuronectes limanda*, Linn.).

Altogether 529 dabs were examined. These were obtained from 15 hauls at 13 localities throughout the district, on various dates in April, May, and June, and the specimens measured from 9 to 31 cms.

The following is a synopsis of the food found in these stomachs:—67 empty, 94 zoophytes, 101 ophiuroids, 29 echinoid spines, 7 *Crangon*, 1 prawn, 69 *Eupagurus*, 22 *Portunus*, 3 *Carcinus*, 5 *Stenorhynchus*, 2 crayfish, 7 *Corystes*, 1 *Hyas*, 1 *Mysis*, 3 *Idotea*, 3 parasitic copepods, 28 amphipoda, 40 chitinous crustacean remains, 12 annelida (unrecognisable), 13 *Nereis*, 20 *Arenicola*, 8 *Aphrodite*, 46 terebellids, 1 serpulids, 22 sabellids, 1 *Nephthys*, 1 *Eulalia viridis*, 6 *Ophioglypha*, 142 *Solen*, 7 *Mactra*, 8 *Pecten*, 6 *Scaphander*, 2 *Scrobicularia*, 23 *Donax*, 57 *Tellina*, 5 *Cardium*, 1 *Lacuna*, 15 *Philine*, 6 *Nucula*, 1 *Syndosmya*, 2 *Buccinum*, 2 *Pleurobranchus*, 1 *Ascidia*, 1 sprats, 1 herrings, 43 *Gobius minutus*, 4 *Ammodytes*, 78 comminuted shells and sand.

From the above it is seen that the dab is an omnivorous feeder, but that crustacea, mollusca, and annelida predominate is evident.

Lemon Soles (*Pleuronectes microcephalus*, Don.).

Lemon soles were obtained at two localities (4 hauls) only, namely, 25 miles W.N.W. of Piel Gas Buoy and 5 miles W.S.W. of Duddon Buoy. Two of the hauls were taken in April, one in May, and one in June. As there were only 9 lemon soles (19 to 34 cms. in length) in these hauls, no great weight can be attached to the results shown here, but I tabulate them for what they are worth. As far as can be judged from these results, annelida seem to be their main food.

4 *Nereis*, 3 terebellids, 2 *Serpula reversa*, 1 sabellids, 1 *Nephthys*, 1 molluscan tissues, 1 amphipoda.

Soles (*Solea vulgaris*, Quen.).

Soles were obtained in 7 hauls at 6 localities (one in Carnarvon Bay) in April, May, and June.

A total of 83 fish (from 11 to 40 cms. in length) were

examined, and, of these, 16 were empty. Annelida seem to be their chief food. The following is a list of the various types of food consumed by soles, and the numbers of stomachs in which each type is found:—16 empty, 4 echinoid spines, 3 heart-urchins, 9 ophiuroids, 1 *Crangon*, 4 *Eupagurus*, 1 *Portunus*, 4 *Idotea*, 2 euphausids, 2 zoeas, 3 crab-remains, 2 annelida (unrecognisable), 15 terebellids, 7 *Arenicola*, 19 sabellids, 22 *Nereis*, 1 serpulids, 2 *Aphrodite*, 1 *Halosydna*, 25 amphipoda, 12 *Solen*, 4 *Cardium*, 10 *Tellina*, 1 *Mactra*, 7 *Philine*, 1 blennioid fishes, 1 mud, 21 sand.

Cod (*Gadus callarias*, Linn.).

Cod were found in 11 hauls at 6 localities (one 11 miles N. by E. from Llandudno Pier, the rest in the North of the District). Of these hauls eight were taken in February, two in April, and one in May.

Altogether 33 cod (measuring from 24 to 102 cms.) were examined, of which 2 were empty. Fish and crustacea seem to be their principal food as shown by the lists:—2 empty, 2 anemones, 7 *Eupagurus*, 6 *Crangon*, 4 prawns, 14 *Hyas*, 12 *Nephrops*, 2 edible-crabs, 7 *Portunus*, 2 *Stenorhynchus*, 2 *Turritella*, 1 *Pecten*, 3 *Buccinum*, 1 *Cardium*, 1 *Eledone cirrosa*, 2 annelida (unrecognisable), 6 *Aphrodite*, 11 whiting, 3 red gurnards, 1 herring, 1 flounder, 2 plaice, 5 soles, 5 solenettes, 4 dabs, 1 dragonets, 1 *Ammodytes*, 7 fish-remains, 2 large stones.

Poor Cod (*Gadus minutus*, Linn.).

One haul on May 14th at 25 miles W.N.W. of Piel Gas Buoy yielded 8 poor cod, measuring from 13 to 29 cms. The following list shows their stomach-contents:—4 *Eupagurus*, 4 *Carcinus*, 2 *Hyas*, 1 *Crangon*, 3 amphipoda, 1 *Pecten*, 1 *Gobius minutus*.

WHITING (*Gadus merlangus*, Linn.).

Whiting were only present in 2 hauls, one on April 22nd at 13 miles S.W. of Morecambe Bay Ship, and one on May 14th at 25 miles W.N.W. of Piel Gas Buoy. Their lengths varied from 17 to 35 cms.

The number obtained for examination was so small (13) that the results given here must only be taken for what they are worth. Of the 13 whiting examined 2 were empty, 5 contained *Crangon*, 1 amphipoda, 1 crab-remains, 1 nereids, 1 *Flustra*, 4 *Pecten*, 1 *Patella*, 3 *Gobius minutus*, 1 sprat, 2 herring, 2 clupeoid fishes.

POLLACK (*Gadus pollachius*, Linn.).

The haul on May 14th at 25 miles W.N.W. of Piel Gas Buoy had 10 pollack, varying in length from 28 to 72 cms. The following shows their stomach-contents:—9 prawns, 4 fish-remains, 1 whiting, 1 sprats, 1 *Ammodytes*, 1 *Eledone cirrosa*.

MEGRIMS (*Lepidorhombus megastoma*, Donovan).

The same haul yielded 2 megrims, measuring 14 and 25 cms. One contained *Crangon*, 2 *Gobius minutus*, 1 fish-remains.

BRILL (*Rhombus laevis*, Rondel.).

Three hauls on May 27th and 28th at 3 localities in Carnarvon Bay contained brill. They measured from 27 to 56 cms.

Of the 18 obtained 3 were empty, 1 contained *Eledone cirrosa*, 6 *Loligo media*, 2 soles, 3 dragonets, 2 plaice, 1 *Gobius minutus*, 3 fish-remains.

TURBOT (*Rhombus maximus*, Linn.).

One specimen obtained on May 29th at 6 miles N. of Great Orme's Head contained 2 large whiting, and many bones of fish; and one from 25 miles W.N.W. of Piel Gas Buoy on June 11th contained fish-remains.

AN INTENSIVE STUDY OF THE MARINE PLANKTON AROUND THE SOUTH END OF THE ISLE OF MAN.—PART VII.

By W. A. Herdman, F.R.S., Andrew Scott, A.L.S., and H. Mabel Lewis, B.A.

This Part gives a brief account of the results obtained during 1913—the seventh year of our detailed analysis of the plankton collected week by week at Port Erin. Our intention is to complete, if possible, ten years of continuous observations before bringing this scheme of work to a conclusion. At the time when this is being written, the eighth year's work has been well inaugurated by the taking during the period of the vernal phyto-plankton of over a hundred special hauls, in addition to the usual weekly gatherings in Port Erin Bay.

The division of labour has been practically the same as in the case of previous reports. The work at sea during April, 1913, was carried on, as before, from the yacht "Runa," with the very efficient help of Mr. H. G. Jackson, M.Sc.; while in Port Erin Bay Mr. Chadwick and Mr. Cregeen, of the Biological Station, collected and preserved about six samples a week throughout the year—two with a fine net (No. 20 silk), two with a coarser (No. 9 silk), and two vertical hauls, from 5 fathoms, at the mouth of the bay.

The authors have divided between them the rest of the work—the examination and calculation and writing out of the results—on the same plan as in previous years.

We do not regard the present report as an exhaustive statement of the results to be obtained from a study of the material collected. These are only of the nature of interim reports. All our samples are carefully retained,

and the detailed lists of identifications and numbers are filed for future reference, and we hope, when the series of observations is completed, to undertake the revision and re-consideration of the whole.

In the meantime we think it useful to issue this report on the more noteworthy features of the year's plankton, and on any new points that we consider require mention or discussion.

For fuller information in regard to our methods, and for the results so far obtained, we must refer readers to the preceding six parts of this report (for 1907-1912).

Material Available.

The collections during 1913 have amounted to 405—all taken within the same limited sea-area off the Isle of Man as in former years. Our table for the whole series of samples from the beginning of the investigation is now as follows:—

Year.	At Sea, from Yacht.		In Bay throughout Year.	Totals.
	Spring.	Autumn.		
1907	218	279	138	635
1908	156	242	157	555
1909	329	147	231 + 49	756
1910	107	249	296	652
1911	120	84	314	518
1912	87	0	299	386
1913	82	41	282	405
Totals ...	1,099	1,042	1,766	3,907

As further material available for comparison, it may be noted that the fishery steamer "James Fletcher" has taken a large number of plankton hauls in other parts of the district during the past year, and these have been worked up by Mr. Riddell; while other samples were taken

from the yacht "Runa," during the summer, off the West Coast of Scotland, and these have also been worked up and reported upon in this volume.

No change has been made in the nets employed or in the method of using them (see former reports).

Plankton of Port Erin Bay in 1913.

As in the last few years, the plan of work has been to take two horizontal (coarse and fine nets), and one vertical haul twice each week throughout the year—that is, about 24 hauls per month. In actual practice the numbers during 1913 were as follows:—

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
No. of Hauls	24	21	24	24	27	24	30	24	27	18	21	18

Over 24 hauls were thus taken in three months, and less than 24 in four months. Bad weather in October and December reduced the number to 18. But on the whole, the work has been carried out for us by Mr. Cregeen with great regularity.

As on previous occasions the vertical hauls at the mouth of the bay are found to agree very well with the larger surface hauls obtained on the same occasions.

The curve for the total plankton reaches to about the same height at the vernal maximum as in 1912, but the secondary rise in autumn does not this time attain to half the height of that in the previous year, and to less than one-fourth of the point reached at the vernal maximum.

We give here, as in previous years, a table showing the monthly averages of the total catch and of the chief

groups of the plankton per haul of the standard net (coarse and fine nets together forming one standard "double haul"). The maxima are printed in heavier type.

1913.	Double hauls.	Average catch.	Diatoms.	Dinoflag-ellates.	Copepoda.	Copepod. nauplii.
January	8	3·6	23,585	657	4,011	1,144
February ...	7	3·6	59,510	2,767	3,877	4,117
March	8	6·7	372,575	6,157	5,723	24,162
April	8	27·3	3,007,444	5,541	8,222	23,894
May	9	**40·1**	**26,927,403**	30,422	11,011	17,189
June	8	33·8	3,010,827	104,131	51,851	**34,150**
July	10	25·2	3,279,375	**145,385**	**54,117**	27,370
August	8	7·3	94,110	69,736	29,751	25,405
September ...	9	8·4	187,578	6,872	39,163	25,089
October	7	3·9	10,170	563	19,961	12,443
November ...	7	4·0	92,031	5,573	30,697	12,284
December ...	6	2·8	36,697	6,015	8,283	2,552

From this table we see that the spring maximum was in May, as it was in 1911, but the increase began earlier, and continued later than in that year. The actual largest haul was 72·2 c.c. on May 16th. In 1912, we noticed that the maximum was spread over a considerable length of time, namely, from March to June, with the highest point in June; this year it is of the same duration (four months), but is from April to July, agreeing in this respect with 1910. The September maximum is much lower than in any previous recorded year, the largest catch being 15·2 c.c. on the 18th, and the average for the month only 8·4 c.c., as against 23·4 c.c., 15·3, 15·6, and 12·1 in the last four years.

It will be noticed on the table that the maximum of the Dinoflagellata and the Copepoda (July) occur much later than that of the Diatoms (May)—the Dinoflagellata being distinctly later than usual.

Diatoms.

It would seem at first sight, from the table given above, that the spring Diatoms compared very favourably as regards numbers with other years, and certainly the maximum is spread over a rather longer period than usual. There were over 4 millions present on two occasions at the end of March, and on July 24th there were over 8 millions, and July 28th nearly 2 millions. But the numbers generally were lower, and the monthly average (nearly 27 millions) given for May is rather misleading as, if we deduct the number obtained in two hauls of a single species, the average for the whole month of all the Diatoms is reduced to less than $4\frac{1}{2}$ millions. The species in question is *Asterionella japonica,* of which 12 million individuals were obtained on May 13th, and 192 millions on May 16th. And this is the more remarkable in that *Asterionella japonica* is an unusual species to be present in any abundance in our district. The way in which, on one occasion, one species, and on another a different species, of Diatoms appears in great profusion, so as to be represented by millions of individuals in one of our standard hauls, suggests that at a time favourable to the growth and reproduction of spring Diatoms in general, it takes very little to give some slight advantage to one of the numerous competing forms, so that it is enabled to forge ahead, and for a short time, at least, far outnumber all the rest—so as to give rise to what appears as a "Rhizosolenia," or a "Chaetoceras," or, as in this case, an "Asterionella" phyto-plankton.

The More Important Genera of Diatoms.

As in former years, we add here a short summary of the distribution throughout the year of the more important Diatoms.

Biddulphia.—This genus is again, as in 1912, represented by a few thousands and tens of thousands only from January to May, and by rather smaller numbers from September to December. It is entirely absent in June, July, and August. In the three years previous to 1912 the numbers reached six figures at the time of the spring maximum, but in 1912 the maximum was only 88,240 (March 11th), and this year only 90,750 (April 24th); and this year the secondary maximum was much smaller and later than in any of the other years, reaching only 20,800 on December 5th.

The above figures represent both species, *B. mobiliensis* and *B. sinensis*, taken together. *B. sinensis*, as usual, does not make its appearance until late in November, while *B. mobiliensis* is frequent from September onwards. Both species continue to be represented throughout the spring and early summer, but *B. mobiliensis* is generally in considerably larger quantities.

Chaetoceras.—In the last three years this genus was present in enormous quantities in spring (nearly 95 millions on April 29th, 1912), and had also a high autumn maximum (nearly 30 millions in 1912). This year, although still the most abundant Diatom in the plankton, the numbers are not nearly so high, and the highest record is only 7,422,000 on April 7th, while in September the numbers only reach 857,500 on the 18th. The monthly average for May is, however, slightly higher than that for April—between two and three millions in each case.

Coscinodiscus.—The genus was well represented during the first six months of the year, starting with a few thousands in each haul in January, reaching 500,000 (the maximum) on April 7th, with the monthly average for April nearly 200,000, dropping to a few thousands again at the end of May, and to a few hundreds at the end of

June. It was then entirely absent from our nets (except in one haul on September 11th, when 50 were taken) until November 1st, and the highest record from then till the end of the year was under 14,000.

Rhizosolenia.—Leaving out of account the abnormally high records for *Rhizosolenia* in 1912, our numbers for the spring and summer of 1913 agree fairly well with former years. It is represented by occasional hundreds only until April, when we get a few thousands; it reaches 706,000 on May 16th, 5,176,000 on June 14th, but the actual maximum is this year in July, not June, with 8,258,000, on the 24th. The numbers then fall to a few tens by the beginning of September, rise to 19,500 on September 18th, and fall again to zero by the middle of October. The genus is only represented on four occasions from November 25th till the end of the year.

Thalassiosira.—The maximum was, as in most years, in May, with 6,580,000 on the 16th, but on no other occasion did the numbers reach the millions. The genus had disappeared by June 17th, and there was no autumn increase, only one haul from that date to the end of the year containing any specimens at all (viz., November 29th, with 50).

Guinardia.—The numbers this year are not so high as in 1912, but are much higher than in 1911. They begin to increase towards the end of March, reach six figures on two dates in May, and seven figures on six occasions from June 11th to July 8th, the latter date having the maximum of 2,260,000, but the highest monthly average is June, with 945,387. The numbers then decrease steadily to zero on August 7th. There is a low autumnal maximum of 27,000 on September 22nd, and from then till the end of the year the genus is usually represented, but by nothing higher than 1,400.

Lauderia.—The maximum is only 601,000 on May 16th, and the highest autumn number is only 8,500 on September 22nd.

Asterionella.—This is a genus which has been represented in the past, so far as our observations show, by comparatively small numbers of the species *A. bleakeleyi*; but this year, in addition to a few thousands of that form in April and May, enormous numbers of a second species, *A. japonica*, appeared for quite a short period in the middle of May, and reached 192 millions in one haul on May 16th.

We add here the table showing the monthly averages of the usual seven genera of Diatoms, together with an eighth, *Asterionella*, which was unusually prevalent this year.

1913.	Biddulphia.	Chaetoceras.	Coscinodiscus.	Rhizosolenia.	Thalassiosira.	Guinardia.	Lauderia.	Asterionella.
Jan. ...	15,925	3,142	3,167	0	0	105	0	0
Feb. ...	27,860	8,349	19,861	111	0	51	74	300
Mar.......	29,487	252,685	86,631	94	187	1,087	580	0
April ...	31,645	2,677,396	195,325	3,875	28,494	14,206	24,750	665
May ...	6,822	2,967,283	19,847	129,178	898,589	78,089	109,144	22,685,144
June ...	0	362,237	756	1,663,669	37,169	945,387	1,452	125
July ...	0	37,075	0	2,574,350	0	655,740	0	0
Aug. ...	0	39,636	0	53,646	0	827	0	0
Sept. ...	374	177,216	6	3,803	0	3,939	1,129	1,100
Oct. ...	1,626	6,579	0	40	0	250	3	10
Nov. ...	6,383	74,086	4,996	19	7	259	0	0
Dec. ...	13,117	6,421	8,266	138	0	432	0	5

This table probably gives quite as clear a picture as we could get from a series of curves to show (1) the waxing and waning of the different generic groups throughout the year, and the manner in which, for example, *Rhizosolenia* is at its maximum just when *Biddulphia* shows a minimum; and (2) the characteristics of each month, beginning with a scanty phyto-plankton of *Biddulphia, Chaetoceras,* and *Coscinodiscus* in January, working up to the maximum

in April and May, when all the generic groups are well represented, then diminishing to a summer minimum in August—and so on.

Dinoflagellata.

The monthly averages for *Ceratium* and *Peridinium* in 1913 were as follows:—

1913.	Ceratium tripos.	Peridinium spp.	1913.	Ceratium tripos.	Peridinium spp.
January	607	15	July	124,930	9,700
February ...	1,933	57	August	67,577	673
March	4,170	12	September	6,720	19
April	3,744	532	October ...	526	31
May	5,367	23,278	November...	5,530	7
June	67,375	25,275	December	5,167	12

The numbers for *Ceratium tripos* are much higher than we have ever had them before, and the maximum is later than in the last two years, being in 1913 in the latter half of July. There were present 225,200 on July 21st, and 239,000 on the 31st, and the numbers continued to be in tens of thousands till almost the end of August.

The actual maximum for *Peridinium* is 100,300 on May 26th, which is a high record as compared with most years, last year's maximum of over 8½ millions being quite unusual, and due probably to an exceptional inflow of Atlantic water in the summer of 1912, bringing various oceanic organisms in increased numbers into our coastal waters.

Noctiluca.

Noctiluca miliaris is represented in our nets during most months of the year 1913, July and December being the two exceptions. There is one haul of 2,000 on August 4th, but the next largest is only 900

(February 24th), and the rest range from a few tens to 800. There is no marked maximum. The characteristic of the year is the constant presence of the organism in small quantity—which is in marked contrast to the occasional phenomenal appearance of *Noctiluca* on the coasts of Lancashire and Wales (or no doubt elsewhere also). On the whole it is more characteristic of *Noctiluca* to be either totally absent or present in great profusion.

Copepoda.

We have again taken out the records of the commonest species of Copepoda, and summarise them as follows:—

Calanus finmarchicus.—There is nothing unusual* about the distribution of this species during 1913. The gatherings are not so large as in 1912, but compare well with other years. The maximum is in July, as has generally been the case, with 4,000 on the 28th. On September 1st there is a large haul of over 3,000.

Pseudocalanus elongatus.—This species is, as usual, well represented in our nets, being present in every haul taken in Port Erin Bay throughout the year. The maximum is in June (50,000 on the 11th, 68,120 on the 24th), and this year the summer maximum is higher than the autumn one, which only reaches 31,130 on August 28th, and 24,350 on September 22nd. In every other year for which we have records, except 1911, when there was no marked autumnal increase at all, the numbers have reached a higher level in autumn than in summer.

Oithona similis.—This is again the most abundant species in our nets. The numbers remain very high (usually tens of thousands) from June to September, the

* Compare the remarks on the distribution of this species on the West Coast of Scotland during the summer of 1913—See this volume, Herdman and Riddell, p. 312.

two highest records being 79,450 and 93,580 on July 21st and 28th respectively. In November the largest haul is 32,860 on the 4th.

Temora longicornis.—The maximum this year is in June with 43,800 on the 11th, the next highest catch being 16,240 on July 21st. The numbers fall off gradually to the end of the year.

Paracalanus parvus.—The curve follows the same general lines as in previous years with its minimum in early summer and its maximum in autumn. The species is entirely absent from our nets from the middle of April until the last day of July; there are a few tens or hundreds present throughout August, rising to the maximum of 31,390 on September 22nd, and the numbers remain in the thousands until the middle of December.

Acartia clausi.—The maximum is in June, with 50,100 on the 2nd, and 39,900 on the 5th, but there is a large haul of 38,880 again on July 31st and another of 44,000 on September 29th.

Anomalocera patersoni.—This species was more abundant in 1913 than in the last few years, but does not reach very high numbers. Entirely absent until the middle of April, it makes its first appearance with 150 on the 18th, and is present in about half the hauls taken from that date to July 11th, after which it is absent (except for one haul containing four specimens on November 7th) to the end of the year. The largest hauls are 1,500 on May 9th, and 440 on June 24th.

Centropages hamatus.—*Centropages* is present on two occasions in March, increases in numbers from April to June, reaches 620 on June 11th and 27th, has 450 on July 21st, and is often present, though in small numbers, to the end of November.

Microcalanus pusillus.—We have only three records

this year, as follows:—April 18th, 100; September 1st, 20; September 4th, 20. So the species is now of no quantitative importance in our district, and we only give its record this year, because of the probably quite exceptional invasion or increase which took place in 1907, and which first drew our attention to this otherwise rare form.

The monthly average hauls for the eight more important species of Copepoda are as follows:—

1913.	Calanus.	Pseudo-calanus.	Temora.	Centro-pages.	Anomal-ocera.	Acartia.	Oithona.	Para-calanus.
Jan. ...	6	859	0	0	0	262	2,722	247
Feb. ...	6	1,134	8	0	0	209	1,954	370
Mar.......	6	2,480	181	3	0	374	2,347	299
Apr. ...	1	3,681	1,757	56	29	755	1,849	17
May ...	14	4,030	859	52	177	4,367	1,478	0
June ...	638	16,944	9,424	235	112	14,399	10,090	0
July ...	1,219	5,874	2,916	165	6	9,282	34,577	50
Aug. ...	77	6,768	1,302	34	0	4,840	16,583	139
Sept. ...	436	9,273	296	19	0	8,180	12,966	7,886
Oct. ...	57	3,236	34	9	0	1,314	8,391	6,456
Nov. ...	17	3,134	2	2	1	1,683	18,291	7,489
Dec. ...	15	1,013	11	0	0	168	4,375	2,668

It seems unnecessary to repeat the diagram we gave last year showing the curves for the chief genera of Copepoda. It is true that the curves in some cases take a slightly different form this year, but the columns of the table enable one at a glance to see what the curve will be like, where the maxima occur, and to what extent the genera agree or differ in their distribution throughout the year. *Paracalanus*, for example, has its minimum at the time of the maximum of *Pseudocalanus*.

Cladocera.

The numbers for this group are not so high as in previous years. As before, the Cladocera are a summer group, only showing, as a rule, between April and September.

Podon intermedium did not appear in the Bay gatherings until April 7th, about a month later than usual. The numbers were low (25 or under) till May 20th, when they rose to 120, and from then till towards the end of July they ranged from zero to 280. From July 24th onwards they were generally, though not consistently, higher. The only three hauls of over a thousand were 1,025 on July 31st, 1,120 on August 21st, and 2,900 on September 1st. After the latter date the numbers dropped, and 22 on October 8th was our last record.

Evadne nordmanni was not represented in our standard hauls until May 20th, when 1,230 were taken. The maximum was reached on June 5th, with 1,630. The numbers dropped to zero on June 20th, and after that the species was only obtained in numbers ranging from 10 to 160, on about half-a-dozen occasions, the last being the 8th of September.

Sagitta.

Sagitta bipunctata was again present throughout the year, being represented in practically all our standard hauls. The maximum is at the end of June with 1,730 on the 24th, and 1,498 on the 27th. There was no increase in late autumn in 1913.

It may be added—although this comes properly into next year's report—that during the Easter vacation work in 1914, when *Sagitta* was being obtained off Port Erin in small numbers in the surface nets, we found that by using weighted nets in a deeper zone of water unusually large hauls of *Sagitta* were obtained. We have had the same experience on occasions in former years, and we are of opinion that the ordinary surface nets do not give any adequate representation of the *Sagitta* fauna.

Oikopleura.

In 1913 *Oikopleura dioica* was represented in all our standard hauls throughout the year. The first record in the thousands was on February 20th (2,670), and from March 10th to November 7th, the numbers were usually in the thousands. The maximum was 34,000 on July 24th. The September increase was not so great as usual, the largest haul being only 9,200 on the 29th. This record differs from that in 1912, when the greatest hauls were in March and September.

Various Larvae.

Echinoderm larvae were unusually abundant in 1913. Absent in January, they appeared suddenly in our nets on February 6th, to the number of 3,040, and attained their maximum of 51,200 as early as February 13th. Other large hauls were 24,080 (February 20th), 17,000 (February 27th), 24,360 (March 10th), and 27,150 (March 13th). The numbers dropped to zero by the middle of April, but Echinoderm larvae were present occasionally from this time on to the end of October, and on July 17th there was a large haul of 30,000 Twice in September the numbers reached the thousands (7,400 on the 11th, and 4,000 on the 18th).

Polychaet larvae were present in most of our hauls in 1913. The largest number obtained in one standard haul was the very high figure of 115,080 on March 3rd. The next highest records are 32,000 on April 10th, and 40,000 on April 15th.

The "Mitraria" Polychaet larvae, as usual, were absent in summer, began to appear sporadically in autumn, increased during winter and reached their maximum in March (7,200 on March 10th, 5,900 on March 22nd, and

10,500 on March 28th). They are characteristically winter and spring forms, present in abundance when the water is at its coldest.

Crab Zoeas occurred in the usual small quantities from February to September. Two hauls only had numbers exceeding a hundred, namely, those on March 30th and July 31st, with 161 and 178 respectively. The highest monthly average was 40 in March. However, we know from former experience that it is largely a matter of accident whether or not our nets encounter a swarm of Crab Zoeas—some of the swarms being of very small extent but densely crowded with larvae.

Mr. H. G. Jackson is making a special study of the larvae of Higher Crustacea (Crabs, Lobsters, &c.) in our gatherings, and will furnish a separate report upon these.

Balanus nauplii were present for the first time on January 25th (1,840), and were in every haul (except one) from that date to June 5th; their final appearance was on June 24th. The maximum was reached on March 26th, with 453,720, the average for the month being 61,394. The next highest record was 255,000 on February 13th. Of the "Cypris" stage very few indeed were present, the numbers ranging from one to seven (with two exceptions of 20 and 23 on May 20th and 23rd), from the middle of April till early in July.

Gastropod larvae were represented in every month in 1913. The highest monthly average was 1,537 for March, and the highest records 3,520 on March 20th, and 3,300 on November 29th.

Lamellibranch larvae were more abundant than Gastropods, and were present in nearly all of the standard hauls taken during the year. Some of the chief hauls were as follows:—19,000 on May 20th, 20,000 on June 11th, 13,100 on June 24th, 10,000 on July 17th,

12,400 on October 20th, 19,500 on October 23rd, and 18,700 on October 27th. It is probable that the Scallop bed (*Pecten opercularis*) opposite the mouth of Port Erin Bay contributes largely to this supply of larvae.

Medusae and Ctenophora.

Medusae were present throughout the year with a maximum in June to July, and a secondary one in September. The chief records were 1,180 on June 11th, 1,820 on June 20th, 1,940 on June 24th, 1,182 on July 21st, 2,015 on July 28th, and 2,657 on September 8th.

Although *Pleurobrachia* did not occur in any numbers in our Port Erin gatherings this year, it seems to have been present in enormous profusion on the Lancashire Coast in July.* Large hauls were obtained in the Barrow Channel and the open sea outside at the beginning of that month, reaching a maximum about July 10th. It is curious that this unusually large swarm did not also appear at the Isle of Man.

Fish Eggs.†

Rockling eggs were present in varying quantities up to the end of September, the maximum being in April, with an average of 123 per haul.

The other fish eggs ranged from the end of January to the middle of August, with a maximum in March of 74 per haul.

The numbers are rather larger this year than last, but it is difficult to attach any significance to these annual variations.

* See remarks by A. Scott, on p. 109 of this volume.

† See also the separate report by A. Scott, at p. 116, dealing specially with the pelagic fish eggs collected by the Fisheries Steamer in various parts of the Irish Sea.

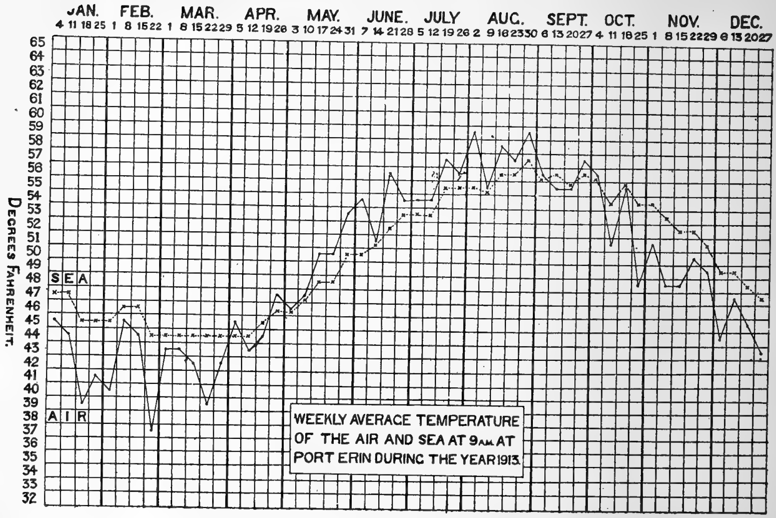
General Remarks.

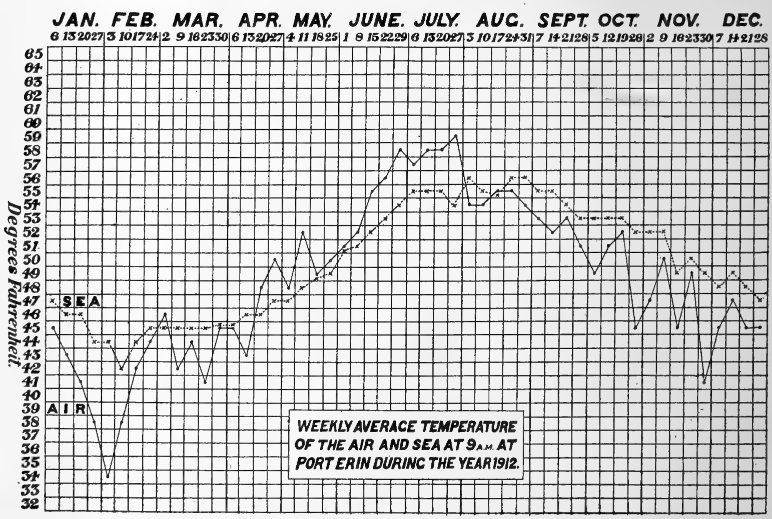
No especially rare forms have appeared in our gatherings during the past year, and we had not so much evidence in the summer of 1913 as in the previous year of a marked inflow of Atlantic water bringing oceanic organisms.

The last three summers have differed considerably in character. That of 1911 was unusually hot and dry, 1912 was wet and stormy, while 1913 was especially fine and calm. Further North on the West of Scotland, 1911 and 1913 were noteworthy for the large swarms of the pelagic Pteropod *Limacina* brought in from the Atlantic, while in 1912 none were present. In this latter year, however, other oceanic organisms, such as *Doliolum*, were carried into the coastal waters. None of these organisms were found in the Irish Sea, and whether any connection can be traced between the variations in the plankton that we have observed and recorded and the weather of these varying summers we cannot yet say. We give on page 386 the usual weather chart for 1913, drawn up by Mr. Chadwick from the daily observations at the Port Erin Biological Station, and we show the similar chart for the previous year (1912) for comparison. Again we notice an unusual run of constant (low) temperatures, throughout March, from the last week in February to the middle of April. The sea was then at its coldest for the whole year.

We do not propose this year to append any remarks on plankton investigations in general, such as formed the conclusion of our last report. We desire now to confine the remaining sections of this report to brief statements of the condition of the plankton each year until we come to our final article, when we hope to give an adequate discussion of the results of the ten years' work.

The present Part, then, is only the necessary contribution for the year 1913 towards that final discussion.


JAN. FEB. MAR. APR. MAY. JUNE. JULY AUG. SEPT. OCT. NOV. DEC.
DEGREES FAHRENHEIT.
SEA
AIR
WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9A.M. AT PORT ERIN DURING THE YEAR 1913.


JAN. FEB. MAR. APR. MAY. JUNE. JULY. AUG. SEPT. OCT. NOV. DEC.
Degrees Fahrenheit.
SEA
AIR
WEEKLY AVERAGE TEMPERATURE OF THE AIR AND SEA AT 9A.M. AT PORT ERIN DURING THE YEAR 1912.

[*Percy Sladen Trust Research.*]

THE NUTRITION AND METABOLISM OF MARINE ANIMALS: THE RATE OF OXIDATION AND OUTPUT OF CARBON-DIOXIDE IN MARINE ANIMALS IN RELATION TO THE AVAILABLE SUPPLY OF FOOD IN SEA-WATER.

By Professor Benjamin Moore, F.R.S., Edward S. Edie, B.Sc., and Edward Whitley, M.A.

(From the Marine Biological Station, Port Erin, and the Bio-Chemical Department, University of Liverpool.)

One of the most important questions in the study of the economic balance of nutrition of the various types of marine animals is that of the source of the food of the higher types, such as molluscs, crustaceans, and fishes.

This question has been discussed, and experimental results bearing on its solution have been described, in a previous paper* by the same authors.

The amount of the dissolved organic matter in sea-water and that of the suspended organic matter in the form of plankton were both investigated, and it was concluded that neither dissolved organic matter nor the *average* amount of suspended plankton sufficed to account for the nutrition of the larger marine organisms. It was pointed out that the larger animals either so distributed themselves along the pathways and situations of a richer supply of food, or actively followed up an unequal distribution of food so as to enable themselves to live upon richer zones of minute organisms, or captured other animals of greater size than minute plankton, which

* *Bio-Chemical Journal*, Vol. VI, 1912, p. 255.

animals in turn fed upon microscopic plankton or upon vegetation along the shore or on the sea-bottom.

In order to approach the matter more closely, it became desirable to estimate in several types of marine animals the daily rate of oxidation and output of carbon-dioxide necessary for the maintenance of the animal, so as to arrive at the daily food quantity necessary in each case.

In the previous paper observations of this kind were made in the case of Sponges, Ascidians, Aplysia, Fusus, Buccinum, Echinus, Asterias, Cancer, Eupagurus, and Blennius (a small fish). It was impracticable at that stage in our work to continue the experiments for a period of much over 24 hours, the maximum period of observation in one case being 48 hours. Also, as no suitable large glass reservoirs were then available, the amount of dissolved oxygen of the sea-water in which the animals were immersed, in certain cases where more active animals were concerned, fell to a very low figure, indeed almost to zero.

These preliminary experiments yielded remarkable results as to the minute amounts of respiratory oxygen upon which marine animals can subsist for a rather prolonged period, but, so far as our immediate quest is concerned, can only be taken as demonstrating the respiratory exchanges during the initial hours in a limited supply of sea-water, and, while giving an approximate idea of the rate at which such animals oxidise their food supply, do not give clear figures as to results over prolonged periods when there is a sufficient supply of oxygen maintained in the water.

Other results of bio-chemical interest were observed in this shorter initial period with rapidly decreasing oxygen supply. It was found, for example, that a large

crustacean can go on for hours living and producing carbon-dioxide in sea-water from which practically all dissolved oxygen has disappeared, and under such conditions the respiratory quotient for the entire period may far exceed unity, rising to a value lying between three and four, and pointing to some molecular rearrangement in the metabolism of the animal. After such exposure to low oxygen values, it was found that the animal recovers perfectly and becomes quite normal within a few minutes when placed in normal sea-water.

But in regard to the normal food requirements and rate of oxidation and output of carbon-dioxide, some more accurate measurements were evidently required, lasting over a much longer period, and with a large volume of sea-water renewed at such intervals that the dissolved oxygen value never fell so low as to embarrass oxidation.

In August and September, 1912, four prolonged experiments were accordingly instituted at the Port Erin Laboratory, in which animals were kept under daily observation for a continuous period of over thirty days, during which interval practically no food was consumed by the animals. Our object, at the outset, was to determine metabolism over an initial period of a few days, and then commence feeding, but the animals refused food under the conditions of captivity. The remarkable result was obtained that the animals gained weight slightly under such conditions, except in one case, and there the loss in weight was small. The animals were all alive and active at the end of the period. The metabolism showed no great falling off in activity throughout the experiments except an apparent one, lasting only a few days in the middle of the interval. This falling off was discovered to be entirely fictitious, and due to a growth of vegetable matter in the reservoirs, for on covering these over to

prevent ingress of light, the metabolic exchanges rose again to their former level.

This growth of vegetation is a factor of error carefully to be guarded against, as the assimilation by green sea-weed is so rapid in good light, that almost all the carbon-dioxide produced by a lobster can be reconverted into oxygen by the vegetation which forms on its own carapace.

Four large carboys, such as are used for the carriage of vitriol, were used for the experiments. The volume of each carboy lay between forty and fifty litres, and is given accurately in the table of each of the experiments. The animals experimented upon were two lobsters, a fish, and an octopus.

The sea-water in the two carboys containing the lobsters was changed once daily in the morning, that being found ample to give sufficient oxygen, and also to give good differences, for purposes of titration, in change in content of the water in oxygen and carbon-dioxide. But in the case of the fish and octopus the oxidations are more rapid, and it was accordingly found necessary to change the water twice daily, in the morning, and late at night. Even with this double change of water, so allowing about ninety litres of sea-water daily, it was usually found that four-fifths to five-sixths of the dissolved oxygen had been removed by the respiration of the animal. It is a remarkable and interesting fact that animals so highly organised as a fish and octopus can stand such an oxygen diminution as this (down to as little as 1·5 milligram of dissolved oxygen per litre) repeated for some hours twice daily for a period of over thirty days, without apparently causing any injury to the animal.

The sea-water supply was obtained by a hose pipe from the elevated outdoor tank of the Biological Station. The station supply is pumped daily into this tank from

Port Erin Bay. The sea-water as it flowed from the supply pipe into the carboys was filtered through the finest bolting silk used for tow-nets, so as to free it from all plankton, although, as shown in our previous paper, this amount of foodstuff would be small, and, as is also shown in our previous paper, the total amount of organic carbon in such filtered water is infinitesimally small and cannot possibly exceed one milligram per litre.

As the carboys were being filled, samples of the water were taken for titration for oxygen and carbon-dioxide.

The oxygen was determined by Winkler's method, and the level of the carbon-dioxide content by titration with centinormal acid, or alkali, in presence of phenol-phthalëin (4 drops in 100 c.c.). These methods are described and discussed in the former paper. The normal figures did not vary much throughout the experiment, the oxygen figure standing at about 8·8 milligrams of oxygen per litre, and the sea-water requiring 2-3 c.c. of N/100 acid per 100 c.c. to give neutrality to phenol-phthalëin.

Similar titrations at the end of each interval for the contents of the carboys gave figures from which oxygen consumed and carbon-dioxide discharged by the animals could be calculated. The carbon-dioxide titration is not nearly so delicate as that for the oxygen, but still the close correspondence in the total figures, for the long interval, between oxygen used and carbon-dioxide evolved, shows that on the whole there is little error in the titrations, for the respiratory quotient in all four cases is practically coincident with unity. The temperature was taken daily throughout the period and varied from a maximum of 15° C. nearly at the beginning in August, to 11° C. about the middle of September.

In changing the water, the carboy was in each case

rapidly emptied of all its water by a wide siphon tube, and care was taken to remove all débris and dejecta from the animal. This precaution is necessary to ensure the health of the animals, and it is remarkable for how long periods small amounts are obtained in absence of all food, apparently due to some continued intestinal excretion. The carboys were then completely filled with fresh sea-water, and closed from the air by tightly fitting cork bungs. In the latter part of each experiment, light was excluded by means of a barrel inverted over each carboy. In the earlier days there was no vegetation, and the results were only interfered with partially for a few days before the use of the barrels began.

The details of the experiments are given in the four following tables:—

Experiment I.

Lobster.—Weight 203-210 grams. Volume of sea-water in carboy = 45·56 litres daily. Duration of experiment, August 10th-September 13th, 1912 = 34 days.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total mg.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total mg.
August 10	6	10	2·38	108	3·2	146
„ 10–11.........	17	50	5·81	265	2·6	118
„ 11–12.........	26	45	5·71	260	6·7	305
„ 12–13.........	18	10	2·84	129	2·2	100
„ 13–14.........	24	0	3·11	142	3·8	173
„ 14–15.........	23	15	3·04	139	3·5	159
„ 15–16.........	23	30	2·89	132	2·9	132
„ 16–17.........	23	50	3·74	170	4·2	191
„ 17–18.........	23	35	3·45	157	4·2	191
„ 18–19.........	23	35	3·38	154	3·2	146
„ 19–20.........	23	55	3·25	148	2·9	132
„ 20–21.........	23	30	2·32	106	3·5	159
„ 21–22.........	23	20	2·75	125	4·2	191
„ 22–23.........	23	55	3·33	152	2·2	100

The experiment was here interrupted, to attempt feeding, from August 23rd to 25th. The animal did not

eat at first, but by August 25th had eaten four small pieces of fish (plaice) weighing about 8 grams.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total mg.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total mg.
August 25–26.........	24	00	4·36	199	2·6	118
„ 26–27.........	23	20	1·24	56	2·2	100
„ 27–28.........	23	55	0·37	17	1·0	46
„ 28–29.........	23	45	3·11	142	2·2	100
„ 29–30.........	23	35	1·40	64	1·9	87
„ 30–31.........	22	45	4·77	217	3·2	146

During the last few days green vegetable matter had appeared in the carboy and on the carapace of the lobster, and the days with a low yield were those of bright daylight. From here on, except where noted, the carboy was covered up by an inverted wooden barrel.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total mg.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total mg.
Aug. 31–Sep 1	23	50	4·86	221	4·2	191
September 1–2	24	00	4·40	200	4·5	205
„ 2–3	24	00	4·04	184	1·6	73
„ 3–4	23	40	4·10	187	4·8	219
„ 4–5	23	50	3·11	142	3·5	159

On September 5th, being a bright sunny day, the covers were left off purposely to observe effects, and see if the falling off previously had been due to photo-synthesis by the plants from the respiratory carbon-dioxide of the lobster.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total mg.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total mg.
September 5–6	23	30	0·06	—	0·6	—

The sea-water at the commencement of this period of 23 hours 30 minutes contained 8·96 milligrams per litre of dissolved oxygen, and at the end 9·02 milligrams per litre, so showing that the small amount of green material within had been more than able to re-synthesise all produced by the animal. If this be contrasted with the

previous two days in darkness, the corresponding figures are 8·81 and 8·96 milligrams at the commencement, and 4·71 and 5·85 milligrams at the end, corresponding to an average consumption of 165 milligrams of oxygen. This illustrates the rate at which the marine plant can synthesise, for the dried weight of vegetable matter inside could certainly not have exceeded 1 gram. The experiment was then continued in darkness, after a day's pause to weigh and attempt feeding the animal. No food was taken, however. The weight of the animal was 205 grams, as against 203 grams at commencement, and this after 26 days practically without food.

Date.		Time Interval.		Oxygen used up.		Oxygen appearing in Carbon-dioxide.	
		h.	m.	Milligrams per litre.	Total mg.	Milligrams per litre.	Total mg.
September	7–8 ...	23	55	2·60	118	4·2	191
,,	8–9 ...	23	20	3·97	181	3·8	173
,,	9–10 ...	23	50	3·11	142	2·9	132
,,	10–11 ...	23	45	3·34	152	3·5	159
,,	11–12 ...	23	50	3·19	145	4·8	219
,,	12–13 ...	23	55	3·85	176	3·8	174

Experiment finished. Weight of animal, 210 grams, that is, 7 grams more than at the beginning of the experiment. It is to be remembered in this connection that this was not a fully-grown lobster, yet the result is interesting. The explanation probably lies in this, that the exo-skeleton continued to grow, and the tissues became less rich in organic substances. The animal was placed in absolute alcohol, and later the proteins, fats, and carbohydrates of the body were estimated, with results to be described later.

So far as we have been able to ascertain, this is the longest experiment yet made on the respiratory exchanges of a large crustacean, with daily determinations of the amount of oxidation. Perhaps the most interesting result is the slowness of oxidation and the correspondingly small amount of food required for the actual metabolic wants

of the animal as an individual. Under normal conditions of freedom of the animal, these would probably be considerably higher, but even if they be placed at double the quantity, they scarcely account for the food a free lobster would use, and this indicates, as has been previously observed in *Echinus esculentus* (3) that a great portion of the daily consumption of food is probably, at this grade of animal life, used for purposes of sexual metabolism.

Thus if the daily consumption of oxygen and output of combined oxygen as carbon-dioxide be totalled up for the entire period, the result appears that the oxygen consumed amounted to 4·760 grams of oxygen, and the oxygen appearing in carbon-dioxide to 4·783. This yields a respiratory quotient of approximately *unity*, indicating that carbohydrate or protein chiefly have been oxidised. The weight of carbohydrate in a combustion is slightly less than that of the oxygen required for its combustion, and a calculation on the assumption that all the material utilised was sugar gives 4·4 grams of sugar. The result would not much vary from this, if protein were being oxidised. If allowance be made for the periods of interruption, and exposure to light, and for changing the sea-water, the interval may be taken very closely as one of 27 days, and on this basis the daily consumption of organic matter reckoned as carbohydrate amounts to only 0·16 gram. It is usual in stating such results to quote the result at so much per kilogram of animal weight. This is a most pernicious custom since the metabolic oxidation is not at all proportional to body-weight, but much more nearly to animal surface, at any rate in warm-blooded animals. If this incorrect method of statement be adopted, the consumption stands at 0·8 gram of carbohydrate per kilogram of body-weight of lobster per diem. This result is confirmed by the next experiment.

It is perhaps better to state that, in absence of food, and in captivity, a lobster weighing approximately 200 grams uses up 0·176 gram of oxygen daily, which would correspond approximately to 0·160 gram of carbohydrate or 0·19 gram of protein.

Experiment II.

Lobster No. 2.—Weight, 240-248 grams. Volume of sea-water in carboy = 46·86 litres daily. Duration of experiment, August 11th-September 13th, 1912 = 33 days.

Date.	Time Interval.		Oxygen used up.		Oxygen appearing in Carbon-dioxide.	
	h.	m.	Milligrams per litre.	Total m.g. in Carboy.	Milligrams per litre.	Total m.g.
August 11–12	25	15	4·92	230	6·4	300
,, 12–13	18	0	3·33	156	3·5	164
,, 13–14	22	50	3·73	175	4·5	211
,, 14–15	23	20	3·35	157	3·2	150
,, 15–16	23	30	3·22	151	2·6	122
,, 16–17	23	50	4·28	200	3·8	178
,, 17–18	23	35	3·58	168	4·2	197
,, 18–19	23	30	3·50	164	3·2	150
,, 19–20	23	50	3·20	150	3·2	150
,, 20–21	23	25	2·58	121	2·2	103
,, 21–22	23	15	2·57	121	1·9	89
,, 22–23	23	55	2·89	135	1·9	89

This animal was not offered food, having been intended originally as a control to the first. The experiment was interrupted for about 1½ hours at this stage for weighing, the animal by an error not having been weighed at the beginning. Weight = 240 grams on August 23rd. Experiment re-commenced.

Date.	Time Interval.		Oxygen used up.		Oxygen appearing in Carbon-dioxide.	
	h.	m.	Milligrams per litre.	Total m.g. in Carboy.	Milligrams per litre.	Total m.g.
August 23–24	22	40	3·03	142	2·2	103
,, 24–25	23	10	3·03	142	2·9	136
,, 25–26	24	05	2·51	118	2·2	103
,, 26–27	23	20	1·76	82	3·8	178
,, 27–28	23	55	2·05	96	1·6	75
,, 28–29	23	45	2·04	96	2·9	136
,, 29–30	23	35	2·16	101	2·2	103
,, 30–31	23	45	3·39	159	3·1	145
Aug. 31–Sep. 1	23	50	3·00	141	2·2	103

The carboy was kept in darkness from this onward, (see note in previous experiment).

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g.
September 1–2	24	00	2·88	135	4·5	211
„ 2–3	24	00	3·11	146	4·6	215
„ 3–4	23	40	2·81	132	4·8	225
„ 4–5	23	55	2·58	121	4·0	187
„ 5–6	23	30	0·96	45	1·0	47

The last day given above was carried on partially in daylight, which accounts, as before, for the drop. The animal was offered food here, but refused it. Weight, 240 grams, as before.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g.
September 7–8......	23	55	4·21	197	3·2	150
„ 8–9......	23	20	3·19	150	2·6	122
„ 9–10......	23	50	2·42	113	1·9	89
„ 10–11 ...	23	45	2·79	131	1·6	75
„ 11–12 ...	23	50	2·63	124	2·9	136
„ 12–13 ...	23	55	2·71	127	3·2	150

Experiment stopped, weight of animal, 248 grams. The animal was preserved in absolute alcohol for analysis of tissues. The total amount of oxygen used up by this lobster amounts to 4·33 grams, and the oxygen appearing in carbon-dioxide is 4·61 grams, yielding a respiratory quotient of 0·93. Making allowances for interruptions, &c., the time-interval totals 27 days, and therefore the daily oxygen consumption averages 0·16 gram, which would oxidise 0·15 gram of carbohydrate or 0·18 of protein. This experiment throughout corresponds very closely with the preceding one, the rate being slightly lower, for the animal was somewhat heavier. It is to be noted that this animal took no food whatever throughout the experiment.

Experiment III.

Fish.—Weight, 270-245 grams. Volume of sea-water = 41·17 × 2 = 82·34 litres daily. Duration of experiment, August 11th-September 13th, 1912 = 33 days.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g. in Carboy.
August 11	8	10	5·29	218	7·3	300
,, 11–12........	10	10	7·14	294	7·0	288
,, 12	13	40	7·33	302	8·6	354
,, 12–13........	13	65	7·33	302	8·3	342
,, 13	9	45	6·22	256	5·4	222
,, 13–14........	13	05	6·37	262	6·4	263
,, 14	10	35	6·27	258	8·0	329
,, 14–15........	12	40	7·63	314	8·3	341
,, 15	10	25	6·82	281	6·4	263
,, 15–16........	12	40	7·12	293	6·7	276
,, 16	10	40	7·04	290	6·7	276
,, 16–17........	12	55	7·26	299	7·6	313
,, 17	10	20	7·11	293	7·0	288
,, 17–18........	12	50	6·59	271	7·0	288
,, 18	10	45	7·11	293	6·7	276
,, 18–19........	12	35	6·66	269	5·8	239
,, 19	10	30	7·19	296	7·3	300
,, 19–20........	13	10	5·70	235	6·4	263
,, 20	11	10	7·26	299	7·6	313
,, 20–21........	11	55	6·44	265	6·7	276
,, 21	10	05	7·55	317	6·4	263
,, 21–22........	12	50	6·22	256	5·7	235
,, 22	10	30	7·63	314	6·4	263
,, 22–23........	13	20	6·22	256	5·7	235
,, 23	9	00	7·55	317	6·1	288
,, 23–24........	13	35	6·44	265	4·8	198
,, 24	9	35	5·19	214	2·6	107
,, 24–25........	13	20	5·63	232	6·4	263
,, 25	10	30	7·29	300	8·0	329
,, 25–26........	12	55	5·14	212	5·4	222
,, 26	9	45	4·82	198	3·5	144
,, 26–27........	13	15	4·89	201	6·4	263
,, 27	9	25	6·00	247	3·5	144
,, 27–28........	14	15	4·15	171	6·3	259
,, 28	9	30	5·85	241	5·4	222
,, 28–29........	13	45	5·26	217	5·1	247
,, 29	9	15	4·87	200	4·8	198
,, 29–30........	13	55	5·02	207	4·0	165
,, 30	8	40	4·44	183	1·6	66

August 30th was a day of bright sunshine, and hence the low figure for oxygen excreted as carbon-dioxide.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g. in Carboy.
August 30–31………	13	25	5·32	219	5·6	230
" 31 …………	9	40	4·04	167	1·9	78
Aug. 31–Sep. 1 ……	13	45	5·97	246	7·0	288
September 1 ………	10	55	3·40	140	1·6	66
" 1–2 ……	12	40	5·32	219	7·0	288
" 2 ………	9	20	2·46	100	0·8	33

From this point onward, till September 5th, the carboy was kept covered up during day.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g. in Carboy.
September 2–3 ……	14	30	4·37	180	4·2	173
" 3 ………	9	35	3·03	124	2·6	107
" 3–4 ……	13	55	4·59	189	4·8	198
" 4 ………	10	30	4·07	168	2·7	111
" 4–5 ……	13	05	4·74	195	6·1	288
" 5 ………	8	50	2·22	91	0·3	(nil).
(In Sunlight)						
" 5–6 ……	14	20	5·63	232	6·0	247

The experiment was here interrupted to weigh the animal and offer food. No food was taken. Weight, 250 grams. Continued in the darkness.

Date.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g. in Carboy.
September 7 ………	9	30	4·08	168	5·1	210
" 7–8 ……	14	10	4·67	192	4·2	173
" 8 ………	10	45	3·48	143	5·4	222
" 8–9 ……	12	15	3·33	137	3·2	132
" 9 ………	10	05	2·37	97	4·8	198
" 9–10……	13	25	3·78	155	4·2	173
" 10………	9	45	2·57	105	5·1	210
" 10–11 …	13	50	3·99	164	5·1	210
" 11………	10	15	1·63	67	4·5	185
" 11–12 …	13	05	2·37	97	4·5	185
" 12………	9	35	2·00	82	3·8	156
" 12–13 …	13	30	4·74	195	4·5	185

The experiment was stopped at this point, after 33 days' duration, when the weight of the fish was found to be 245 grams, and it was placed in alcohol for subsequent analysis of the tissues. The total amount of oxygen used up in the 33 days was 14·01 grams, and the oxygen given out in form of carbon-dioxide was 14·27 grams. The weights of the fish at intervals were as follows:—At start, August 11th, 270 grams; August 23rd, 249 grams; September 6th, 250 grams; September 13th, 245 grams. Although there is an initial drop in weight of about 20 grams between August 11th and August 23rd, from this date onward throughout the remainder of the experiment the weight is practically constant. Since oxygen weighing 14 grams is consumed representing an equal dry weight approximately of carbohydrate or protein combusted, the wet weight of the fish ought to have dropped approximately by about 40 to 50 grams. Therefore, either food from some unknown source must have been consumed or the tissues must have been more heavily charged with water towards the end, and less with organic matter. The later work to be recorded on the lobster shows that the second is the correct one of these two hypotheses.

The addition of the time-intervals of observation given in the table yields 30 days, 23 hours, and 10 minutes, which may be taken approximately as 31 days, and on this basis the daily uptake of oxygen for a fish of 270 to 240 grams amounts to only 0·45 gram, and the output of oxygen in carbon-dioxide to 0·46 gram. The slightly high figure for carbon-dioxide is probably due to experimental error, and the respiratory quotient lies very near to unity.

Experiment IV.

Octopus.—Not weighed at beginning on account of liability to injury in weighing, weight at end on September 13th, 1912 = 370 grams. Duration of experiment from August 12th, till September 13th = 32 days. Daily volume of sea-water = 47·895 × 2 litres = 95·79 litres.

Date 1912.	Time Interval. h.	m.	Oxygen used up. Milligrams per litre.	Total m.g. in Carboy.	Oxygen appearing in Carbon-dioxide. Milligrams per litre.	Total m.g. in Carboy.
August 12	4	50	4·01	192	6·1	292
„ 12–13.........	14	00	6·63	317	7·0	335
„ 13	9	30	4·95	237	7·3	349
„ 13–14.........	13	10	6·03	288	6·7	320
„ 14	10	40	4·27	205	7·0	335
„ 14–15.........	12	30	5·73	275	6·4	306
„ 15	10	25	4·37	210	5·4	259
„ 15–16.........	12	35	7·29	349	7·0	335
„ 16	10	30	7·12	341	6·4	306
„ 16–17.........	12	50	7·89	378	7·3	349
„ 17	10	10	7·58	363	7·0	335
„ 17–18.........	12	45	7·96	381	7·0	335
„ 18	10	35	7·66	367	7·3	349
„ 18–19.........	12	30	7·81	374	6·4	306
„ 19	10	25	7·50	359	7·3	349
„ 19–20.........	13	05	8·12	389	8·3	397
„ 20	11	05	7·11	340	7·0	335
„ 20–21.........	11	50	7·34	351	6·3	301
„ 21	10	00	6·64	318	5·4	259
„ 21–22.........	12	45	7·72	369	5·7	274
, 22	10	25	6·72	321	6·1	292
„ 22–23.........	13	15	7·96	381	6·7	320
			Total	7,205	Total	7,038

Experiment interrupted. Food offered, but little or none taken.

Date.	Time Interval. h.	m.	Oxygen used in m.g. per litre.	Total O_2 used 7,205.	Oxygen excreted as CO_2 in m.g. per litre.	Total O_2 excreted as CO_2 7,038.
August 25	9	40	5·91	284	5·4	259
„ 25–26.........	12	50	7·61	364	7·7	368
„ 26	9	40	3·52	169	1·6	77
„ 26–27.........	13	10	5·45	260	8·6	412
„ 27	9	15	2·89	139	0·3	nil.
„ 27–28.........	14	10	5·28	253	7·0	335
„ 28	9	20	4·42	212	4·2	202
„ 28–29.........	13	40	5·88	282	5·8	278
„ 29	9	05	3·03	145	2·0	96
„ 29–30.........	13	50	5·64	270	5·2	250
„ 30	8	30	6·71	321	4·0	192
„ 30–31.........	13	15	8·41	403	9·6	460
„ 31	9	30	5·84	280	3·5	168
Aug. 31–Sep 1	13	40	8·15	390	9·7	464
September 1	10	45	7·56	362	5·3	254
„ 1–2	12	35	7·72	369	5·7	274
„ 2	9	05	5·88	282	3·0	144
„ 2–3	14	25	8·35	400	8·5	407
„ 3	9	15	6·89	330	6·0	287
„ 3–4	13	50	8·12	389	9·5	455
„ 4	10	25	6·19	296	4·5	216
„ 4–5	13	00	6·57	314	7·4	354
„ 5	8	40	1·42	Cover off 68 In daylight	0·6	nil.
„ 5–6	14	15	4·50	Part daylight 216	5·8	278
				14,003		13,267

Experiment interrupted. Animal offered food. None taken.

Date.	Time Interval. h.	m.	Oxygen used in m.g. per litre.	Total O_2 used 14,003	Oxygen excreted as CO_2 in m.g. per litre.	Total O_2 excreted as CO_2 13,267
September 7	9	25	4·74	227	3·2	154
„ 7–8	13	55	7·44	356	6·7	320
„ 8	10	35	6·96	333	8·5	407
„ 8–9	12	10	6·58	315	6·7	320
„ 9	9	55	4·49	216	5·4	259
„ 9–10......	13	20	6·49	311	7·1	340
„ 10.........	9	35	5·17	248	5·8	278
„ 10–11 ...	13	45	6·48	310	4·8	230
„ 11.........	10	10	5·25	252	8·0	383
„ 11–12 ...	13	0	6·09	291	5·4	259
„ 12.........	9	30	4·47	215	6·4	306
„ 12–13 ...	13	25	6·17	295	6·4	306
				17,372		16,789

Experiment stopped. Weight of animal = 370 grams.

The added time-intervals for which the oxygen intake and carbon-dioxide output were estimated amount to 27 days, 16 hours, 25 minutes, and the oxygen used up totals 17·372 grams, and output of oxygen in carbon-dioxide to 16·789 grams. The daily quantity of oxygen exchange is very approximately 0·6 gram.

The weight of the animal at the start could not be taken, but as it was 370 grams at the finish, it may be taken roughly as averaging 400 grams during the experiment. The result is, therefore, that an octopus weighing 400 grams consumes 0·6 grams of oxygen daily, and the respiratory quotient is practically unity. This shows a much higher metabolic activity for this species of animal than for a lobster, and one that is approximately equivalent to that of the fish. For, if the metabolism be taken as proportional to the surface and an octopus of 400 grams uses up 0·6 gram of oxygen daily, then one of 250 grams will use up an amount of 0·46 gram, while the fish in Experiment III., weighing 240-270 grams used up 0.45 gram daily, the corresponding figure for the lobsters lies at about one-third of this amount, namely, 0·16 to 0·18 gram daily.

In a free condition and when feeding the metabolism would naturally be higher, but even if the figures be doubled, an extraordinarily low metabolism is revealed. For, a wet weight of about three grams of animal matter daily would appear to be enough to maintain a fairly large fish or octopus, and one-third of that amount to maintain a lobster. When feeding, such animals almost certainly consume many times this quantity of food daily, and hence it becomes obvious that the greater portion of the food supply is utilised for intermediate metabolism, and for the production of the organic matter required in their

sexual metabolism, and is not oxidised to carbon-dioxide to supply muscular and other energy for the animal itself.

The minute muscular metabolism is probably explicable on two grounds; first, there is little or nothing required for maintenance of temperature, and secondly, the animal is balanced or counterpoised in the water, so that the loss in locomotion and swimming up and down is also reduced to a minimum.

At the commencement of the experiments it was not anticipated that at the conclusion of a fast of over thirty days the weight of the lobsters would have remained constant, or even slightly increased, while that of the fish after a small initial drop would also remain practically constant during a period of three weeks, throughout which no food was taken. As a consequence no normal animals of the same species and size were fixed for determination of proteins, fats, and carbohydrates in the tissues at the start, and comparison of these with like data for the experimental animals at the conclusion of the fast. Accordingly from this set of experiments *alone*, no conclusion could be drawn as to whether the energy for the metabolism was derived from a dilution, or water-logging of the tissues, or possibly, as suggested by Pütter, from dissolved organic matter contained in the filtered sea-water supplied daily to the animals. The excessively minute amount of dissolved organic matter (if any) contained in sea-water as shown by our previous experiments appeared to us, however, to negative the latter view. To decide this point the prolonged series of experiments upon lobsters detailed in the succeeding paper of the series were set in progress. These experiments demonstrate that the necessary energy is mainly derived from the proteins of the animal's tissue just as in the later stages of inanition of terrestrial animals, but in the case of aquatic animals

the metabolic exchanges are so slow that a period of several weeks' duration becomes necessary, in order to show the result clearly. When sufficient time is given, however, the proteins become much reduced, and the loss is sufficient to account for all the energy required for the metabolism of the fasting animal.

In conclusion, the results of the examinations of the tissues of the four animals are given; those in the case of the lobsters may be compared with the similar results in the succeeding paper. It is noteworthy that carbohydrate is absent, but, strange to say, even in normal lobsters the amount of glycogen or other carbohydrate is excessively low; whether this is a seasonal result, or is always the case, we have not at present determined.

Immediately at the end of the experiments the animals were weighed, killed, and preserved by placing in excess of absolute alcohol. After some weeks, the alcohol was separated and taken down to dryness, the soft parts were then separated, dried, and reduced to a powder, the hard parts were similarly treated, and then the soft parts and hard parts were thoroughly mixed and incorporated by grinding up together in a mortar. The mixed powder was then dried in a desiccator over sulphuric acid, and weighed, so giving, on addition of the dry weight of the alcoholic extract, the total dried weight as shown in the table. The dried powders from the four animals were preserved for the analyses in dried glass-stoppered wide-mouthed bottles. The figure given as protein is the total nitrogen figure from a Kjeldahl multiplied by the factor 6·25. It is probably a little too high, but there is very little nitrogen present other than protein nitrogen.

Fats were determined in the usual way from Soxhlet extractions with ether. Glycogen was absent throughout. "Extractives" means alcoholic extractives less fats. The

ash was obtained by incineration. For the carrying out of these analyses our thanks are due to Mr. W. H. Evans, B.Sc.

Composition of Animals at end of Fasting Period.

Lobster No. 1.—Live weight, 210 grams.
Dry weight, 71·6 grams.

Constituents.	Weight in grams.	Percentage of dry weight.
Proteins	32·23	45·02
Fats	3·51	4·91
Glycogen	Nil.	Nil.
Extractives (non-fatty)	5·22	7·27
Ash	23·20	33·80
Undetermined	7·44	9·00

Lobster No. 2.—Live weight, 248 grams.
Dry weight 91·26 grams.

Constituents.	Weight in grams.	Percentage of dry weight.
Proteins	39·90	43·71
Fats	3·45	3·78
Glycogen	Nil.	Nil.
Extractives (non-fatty)	10·22	11·20
Ash	29·66	32·50
Undetermined	8·03	9·81

Fish (*Gadus virens*, Linn.).—Live weight, 245 grams.
Dry weight, 74·9 grams.

Constituents.	Weight in grams.	Percentage of dry weight.
Proteins	45·71	61·20
Fats	14·01	18·76
Glycogen	Nil.	Nil.
Extractives (non-fatty)	3·86	5·16
Ash	10·46	14·00
Undetermined	0·66	0·88

Octopus.—Live weight, 370 grams.
Dry weight, 89·37 grams.

Constituents.	Weight in grams.	Percentage of dry weight.
Proteins	50·72	56·75
Fats	20·65	23·10
Glycogen	Nil.	Nil.
Extractives (non-fatty)	12·78	14·30
Ash	3·57	4·00
Undetermined	1·65	1·85

The considerable amounts of fat in the tissues of the fish and octopus after a whole month of fasting are remarkable; the corresponding figures in the two lobsters are low, but a comparison with the figures for normal freshly-caught lobsters as shown in the succeeding paper show that there is no very great reduction in fats as a result of the fasting, the normal percentage of fat in this animal being a low one.

It is of interest to consider the figures from the point of view of Pütter's theory that such marine animals obtain a large percentage or the whole of their nutrition not in particulate form, but as dissolved organic matter.

In his earlier work, through the use of faulty analytical methods, this observer claimed to have demonstrated a considerable amount of dissolved organic matter in sea-water, reaching to as much as 134 milligrams per litre.

At a later period Pütter reduces his assumption of the content of dissolved organic matter in sea-water to 4 or 5 milligrams per litre, chiefly as a result of the re-determinations of the *maximum* possible amount of dissolved organic matter by Henze as lying below 3 to 4 milligrams per litre. Henze states in his paper, however, that the amount is so small as to be indeterminate and within the limits of experimental error. He does not state that sea-water actually contains 3-4 milligrams of organic matter per litre, although Pütter assumes this as a deduction apparently from Henze's work in all his later papers. From our own previous experiments, we feel convinced that organic matter in solution is practically absent from pure sea-water. Pütter, while agreeing that the content of sea-water in dissolved organic matter is much less than his original estimate, still adheres to his original view, in spite of the change of

figures, that dissolved organic matter is the most important food supply for the majority of aquatic organisms.

Our own previous work demonstrated to us that the amount of dissolved organic matter in pure sea-water such as is found at Port Erin is so small as to be undeterminable by any known chemical method, and certainly falls below 1 milligram per litre.

It is, hence, impossible that in the foregoing experiments the animals could have been supported by the organic matter dissolved in the sea-water, for the very *utmost* available organic matter, even if the organism removed every trace from the sea-water, would have been 45 milligrams daily for each of the lobsters, and 90 milligrams each for the fish and octopus. Now the lobsters used up daily oxygen equivalent to about 160 milligrams of organic matter, and the fish an amount equivalent to 450 milligrams, and the octopus to 600 milligrams.

The Pütter hypothesis as to feeding by dissolved organic matter accordingly yields no explanation for the slower falling off in the weights, and as the subsequent experiments show this is due solely to increased water content of the tissues.

Moreover, the above experiments show the impossibility of Pütter's position, by exactly similar reasoning to that which he himself uses in proving the inadequacy of the average plankton distribution as a food supply, namely, the inordinate volume of water which would require to be entirely cleared of dissolved organic matter in order to furnish sufficient nutrition.

If the figure we have stated as the *maximum* possible for dissolved organic matter in pure sea-water, viz., one milligram per litre, be taken as the basis of calculations, then to keep in equilibrium from this source by *complete* abstraction of organic matter from the water coming in

contact with the gills or other absorptive organs, the lobsters in our experiments would be required to completely clear 160 litres, the fish 450 litres, and the octopus 600 litres of sea-water daily of all trace of organic matter.

Even if Pütter's own most recent figures for organic matter of 4 milligrams per litre be taken, then the figures become 40, 112, 150 litres, and this suggestion, especially in absence of any attempt at direct experimental proof, seems to us to be ruled out by its inherent absurdity. It is impossible to believe, in absence of all attempt at proof, even admitting that sea-water contains 4 parts in a million of some hypothetical and unknown form of organic matter, that this organic matter can, in some way, be entirely removed from the water passing in contact with the gills of a fish, of only about 250-270 grams in weight, to the extent of at least 112 litres of sea-water every twenty-four hours.

Such an uptake of dissolved organic matter in exceedingly dilute solution from a comparatively large volume of sea-water could only occur if, in the fish gill, there were exposed a substance with a specific high avidity for the dissolved organic matter, comparable to that of haemoglobin and similar bodies for the dissolved oxygen of the water. Both the dissolved organic matter and the body possessing ability for its absorption are, however, purely hypothetical, and so the Pütter hypothesis rests on no observed facts, and is incompatible with all recent determinations.

It is, in our view, definitely settled by experiment, that sea-water does not contain any appreciable amount of organic matter capable of acting as a nutrient medium for aquatic animals.

In this paper we have also obtained, over longer periods, figures indicating the rates of oxidation in larger

marine animals, and have definitely shown that the preponderating amount of food consumed by such animals is utilised for increases of the animal by growth and for sexual reproduction, and that but a small fraction is oxidised for the metabolic needs of the animal in other activities than growth and reproduction.

Our thanks are due to Mr. W. H. Evans and Mr. Arthur Webster for much assistance in the chemical analyses, and to the Trustees of the Percy Sladen Memorial for the necessary funds to carry out the work.

[*Percy Sladen Trust Research.*]

THE NUTRITION AND METABOLISM OF MARINE ANIMALS:—THE EFFECTS IN THE LOBSTER OF PROLONGED ABSTENTION FROM FOOD IN CAPTIVITY.

By Professor B. Moore, F.R.S., and George A. Herdman

(From the Marine Biological Laboratory, Port Erin, and the Bio-Chemical Laboratory, University of Liverpool.)

The remarkable fact recorded in the previous paper,* that lobsters in captivity in glass carboys refuse food, even after days of abstention, and under such conditions do not diminish, but often increase, in live body-weight, appeared to demand more extended observation, especially since no control animals had been preserved and set aside at the outset of the experiments for comparative observation. Without such control observations, on the ratio of live weight to dry weight of tissues, and the composition of the latter in carbohydrate, fat, protein, and inorganic matter, it becomes difficult on account of the slow rates of oxidation to be quite certain of the source of the energy utilised by the animal during such a prolonged period of inanition.

Accordingly, three series of experiments were instituted, in each of which four lobsters were used. The animals were chosen of convenient size for introduction into the large vitriol carboys described in the previous paper, and after weighing them they were so distributed in the batches that the aggregate weights were nearly balanced.

* See p. 387.

One set of four lobsters were immediately killed by immersion in absolute alcohol, and preserved in this fluid for some months to furnish control observations of dry body-weight, proteins, carbohydrate, fat and ash at the end of the experiments.

The second batch of four lobsters were placed in the four carboys, which were freshly filled daily with sea-water, as described in the preceding paper, with the exception that the water was not filtered through silk, so that the animals could have had the whole of any possible nutritive material contained in the daily 40-50 litres of sea-water that formed their supply. The animals had no food whatever during the experiment. Daily determinations of oxygen consumed and carbon-dioxide formed were carried out over the period from April 9th till May 11th, 1913, that is to say, a period of 32 days, and these showed throughout a somewhat slower metabolism than in the summer months, as recorded in the previous paper, the daily intake of oxygen averaging 120 milligrams per lobster, instead of the 160 milligrams of the summer months. Apart from this slower rate, the results are exactly similar to those detailed before, and so the tables of the experiments need not now be reproduced.

At the end of the thirty-two-day period, the animals were weighed, the weights showing practically no change as a result of the 32 days' fast. Thus the weights before were 218·3, 292·4, 258·0, and 265·6 grams, and afterwards 221·0, 291·5, 255·4, and 265·3 grams respectively—the aggregate weight at the start was thus 1034·3 grams, and at the end 1033·2 grams. After weighing, these four lobsters were placed in absolute alcohol, and preserved therein like the controls.

The third series of four lobsters were weighed and placed in the four carboys, soon after the conclusion of

the above experiment on May 14th, 1913. No daily analyses of oxygen and carbon-dioxide were made as previous research supplied the necessary information on this point, and the object was to make as prolonged an experiment as possible. The water was changed daily throughout the entire period of over seven months that this experiment lasted, so that each animal had an allowance daily of 40 to 50 litres of fresh sea-water. The four carboys were kept covered up from the light by tarred black canvas covers throughout the duration of the experiment, except during the few minutes each morning when the water was being changed.

The complete duration of the experiment was from May 14th, 1913, till January 4th, 1914, a period of 235 days. Two of the animals (Nos. 1 and 4) lived throughout the entire period, and weighed as much at the end as at the beginning, the other two died while shedding their shells, one early in the experiment on June 14th, 1913, the other (No. 3) nearly at the end, on November 14th, 1913. The lobster which died on June 14th was omitted from consideration, and replaced by another (No. 2) on June 18th, and this animal remained alive and active till the end of the experiment, on January 4th, 1914. The weights of the animals during the experiment were as follows:—

Lobster No. 1: May 14th, 1913, weight, 301·9 grams; June 14th, 1913, weight, 303·4 grams; January 4th, 1914, weight, 301·7 grams.

Lobster No. 2: June 18th, 1913, weight, 271 grams; January 4th, 1914, weight, 270·5 grams.

Lobster No. 3: May 14th, 1913, weight, 220·7 grams; June 14th, 1913, weight, 223·5 grams. (Died November 14th, 1913).

Lobster No. 4: May 14th, 1913, weight, 224·7 grams; June 14th, 1913, weight, 227·3 grams; January 4th, 1914, weight, 226·4 grams.

The remarkable fact comes out from these figures that the live weight of each lobster shows a tendency to increase, even in a period of complete absence of feeding of over seven months. Thus in the case of Lobster No. 1, after more than seven months, the weight is 301·7, instead of 301·9 at the beginning, and in the case of Lobster No. 4, the corresponding weights are 224·7 grams at the beginning, and 226·4 at the end, an actual increase of 1·7 grams after over seven months without food.

It looks at first sight as if the animals were obtaining ample nutrition from the pure sea-water alone, but the analytical results furnish the explanation, which is, that the tissues are simply becoming more and more water-logged, or diluted in their content of organic matter. The metabolism of the animal, so far as its own individual needs are concerned, is so slow that there is ample provision for an existence of many months without food.

The rate of oxidation is also slowed during the later part of the seven months' period. To illustrate this the oxygen consumption of three of the animals on the first and last days of the period may be cited as follows:—

Lobster No. 1: At commencement (May, 1913), oxygen consumption 120 milligrams per diem; at end (January, 1914), 75 milligrams per diem.

Lobster No. 2: At commencement (June, 1913), 140 milligrams per diem; at end (January, 1914), 84 milligrams per diem.

Lobster No. 4: At commencement (May, 1913), 140 milligrams per diem; at end (January, 1914), 80 milligrams per diem.

Attention may now be turned to the amounts of oxidisable material in the three sets of lobsters as shown by the analyses made at the end of the experiments. The tables show that there is a distinct difference after a month of fasting, but at the conclusion of the seven months' period the oxidisable substances are so markedly

reduced that they amount to less than half the original quantities.

The methods of analysis were as described in the previous paper.

Control Lobsters.

	Live Weight In grams	Dry Weight	Protein N x 6·25 per-centage	Fat per-centage	Alcoholic Extractives non-Fatty per-centage	Glycogen per-centage	Ash per-centage	Undetermined per-centage
No. 1	279·8	92·29	34·27	2·39	5·74	Absent.	49·07	8·53
No. 2	291·5	73·98	29·56	6·96	10·35	,,	50·60	2·53
No. 3	325·0	122·46	36·46	6·18	8·02	2·01	39·83	7·50
No. 4	213·9	79·04	35·04	4·60	8·84	1·91	42·82	6·79
Totals	1110·2	367·77	—	—	—	—	182·32	—
Averages	277·5	91·94	33·83	5·03	8·23	0·98	45·58	6·33

Batch No. 1.

Experiment from April 9th till May 11th, 1913 = 32 days.

	Live Weight In grams		Dry Weight In grams	Protein N x 6·25 per-centage	Fat per-centage	Alcoholic Extractives non-Fatty per-centage	Glycogen per-centage	Ash per-centage	Undetermined per-centage
	Beginning	End							
No. 1	218·3	221·0	87·37	37·25	3·84	11·72	2·64	42·21	2·34
No. 2	292·4	291·5	105·37	35·25	4·94	7·88	Absent.	43·62	8·31
No. 3	258·0	255·4	80·68	28·32	3·16	10·27	,,	53·38	4·87
No. 4	265·6	265·3	63·85	30·94	2·28	12·04	,,	53·31	1·41
Totals	1034·3	1033·2	337·27	—	—	—	—	—	—
Averages...	258·6	258·3	84·31	32·94	3·55	7·97	0·66	48·13	6·73

Batch No. 2.

Experiment from May 14th, 1913, till January 4th, 1914 = 235 days.

Lobsters No. 1 and No. 4 are for the entire period. Lobster No. 2 from June 18th, 1913, till January 4th, 1914 = 200 days, and Lobster No. 3 from May 14th, 1913, till November 4th, 1913 = 184 days.

	Live Weight In grams		Dry Weight In grams	Protein N x 6·25 per-centage	Fat per-centage	Alcoholic Extractives non-Fatty per-centage	Glycogen per-centage	Ash per-centage	Undetermined per-centage
	Beginning	End							
No. 1	301·9	301·7	60·13	22·11	2·56	8·54	Absent.	65·90	0·79
No. 2	271·0	270·5	77·67	21·30	0·99	9·12	,,	65·40	3·19
No. 3	220·7	—	39·23	18·04	3·59	12·05	,,	65·56	0·76
No. 4	224·7	226·4	61·79	23·75	1·44	7·00	,,	62·45	5·36
Totals	1018·3	1019·3	238·82	—	—	—	—	—	—
Averages...	254·5	254·8	59·70	21·30	2·14	9·17	,,	64·82	2·52

Although the live weight remains constant, even after more than 200 days without food, the analyses show that the total dried weight has fallen from an average of 84·31 to 59·70, and this reduced dried weight also consists much more largely of inorganic constituents, for the ash of the normal lobster averages 48·13 per cent. of the dried weight, while the ash of the lobsters kept without food averages 64·82 per cent. of the dried weight.

The ash subtracted from the total dried weight gives the total organic matter, and when this operation is carried out it appears that the control lobsters possess 51·87 per cent. of their weight as organic matter, while the experimental lobsters have only 35·18 per cent. of their weight as organic matter. If now these percentages be applied to the actual dried weights in grams, then it appears that the average weight of organic matter in the four control lobsters is 43·73 grams, while the corresponding average for the four experimental lobsters which fasted through the more prolonged periods is 21·00 grams. The difference in these two figures gives the amount of organic matter upon which the animals have subsisted. It averages for each lobster 22·73 grams, and the period without food averages 213 days. The daily consumption of organic matter from the tissues of the animal accordingly averages 107 milligrams.

The details of analysis given in the table demonstrate that the organic matter undergoing oxidation is mainly protein, and for protein the weight of oxygen for combustion slightly exceeds the weight of the dry protein, so that the consumption daily of 107 milligrams of protein would mean the disappearance each day of 120 to 130 milligrams of oxygen on an average throughout the period.

The actual determinations of oxygen as stated earlier

in the paper show a consumption of 120 to 140 milligrams daily at the start in May. The consumption probably increased somewhat with the temperature in the summer, and then slowed down as winter approached, and as reserves of organic foodstuffs began to be exhausted, so as finally to drop to about one-half at the end of the experiment.

There is accordingly no need to call in any hypothetical dissolved organic matter in the sea-water to account for the experimental results. The animals are able to survive all these months because the rate of oxidation to supply their own individual needs is so small, and when the loss of organic matter is calculated out as above, it is found to balance fairly accurately with the daily consumption of oxygen.

The aggregate weights of the four lobsters in the three batches are not very widely removed from one kilogram, and it facilitates comparison to reduce each batch to an equal weight. This calculation has been made in the following table which shows quantities per 1000 grams of live weight.

Comparison of Constituents in 1,000 Parts of Live Weight.

Batch	Dry Weight	Ash	Total Organic Matter	Protein	Fat	Alcoholic Ex-tractives	Glycogen	Undetermined
Controls ...	331·2	151·69	180·14	112·04	16·66	27·26	3·25	20·98
Batch No. 1	326·1	156·96	169·15	107·42	11·57	26·00	2·17	21·95
Batch No. 2	235·4	152·38	82·12	49·31	4·72	21·15	Absent.	5·91

Attention may be drawn to the remarkable constancy of the ash representing the inorganic constituents in the above comparison. A fast of over seven months, which reduces the organic matter by well over one-half leaves the inorganic constituents as at the beginning. Turning to the organic constituents, by taking differences from the controls, the amounts of protein, carbohydrate, and fat,

combusted in the time-intervals of the two experiments, may be fairly closely determined. It is clearly to be remembered that this is not the metabolism rate for a single lobster of 1,000 grams, but the average metabolism rate of four lobsters roughly aggregating 1,000 grams in weight, and proportionately reduced for purposes of comparison to 1,000 grams.

The consumptions are as follows:—

CONSUMPTION OF FOOD IN GRAMS PER KILOGRAM OF LOBSTER.

Average Time Interval	Total Organic Matter	Protein	Fat	Glycogen	Alcoholic Extractives	Undetermined
32 days	10·99	4·62	5·09	1·08	1·26	0·97
213 days ...	98·02	62·73	11·94	3·25	6·11	15·07

From this the daily consumption comes out as follows:—

DAILY FOOD CONSUMPTION PER KILOGRAM OF LOBSTER.

	Total	Protein	Fat	Glycogen	Alcoholic Extractives	Undetermined
1st Batch ...	0·34	0·14	0·16	0·03	0·04	0·03
2nd Batch ...	0·46	0·29	0·06	0·01	0·03	0·07

A contrast of the shorter experiment with the longer one shows that proportionately more fat and carbohydrate are oxidised in the early stages, while in the later stages of inanition the consumption is mainly protein, although, as shown by the preceding table, some fat is still present.

SUMMARY.

1. Lobsters provided daily with a sufficient supply of fresh sea-water can be preserved alive without food during a period of over seven months.
2. The live body-weight of such lobsters does not diminish during such a prolonged period of inanition. But while the actual weight of inorganic matter remains constant, the total dry weight and total organic weight

are markedly diminished, and as a result the *percentage* of inorganic matter in the dry weight becomes increased.

3. As a result of the inanition the total oxidisable organic matter may fall to considerably less than one-half of the initial amount.
4. At the commencement of the period, protein, fat, and carbohydrate are oxidised almost equally, later the carbohydrate becomes exhausted, and although fat is still present, nearly all the oxidation falls upon the proteins.
5. There is a satisfactory correspondence between the amount of oxygen consumed by the animals throughout the period and the amount of organic matter disappearing. The oxygen consumed corresponds very closely to that required for oxidation of the organic matter disappearing, so that there is no reason to suppose that the animal utilises any dissolved organic matter which might hypothetically be present in the sea-water.
6. The rate of oxidation is throughout a slow one representable by 120 to 130 milligrams per lobster of 220-300 grams at the commencement, and dropping to about half this quantity towards the end of the experiment. This amount corresponds to a little over one-tenth of a gram of protein or carbohydrate daily.

FURTHER NOTE ON DECAPOD LARVAE IN THE IRISH SEA.

By H. G. Jackson, M.Sc.

Introductory.

The short report which follows is limited in scope. It contains an account of the organisms captured in the sea round the south end of the Isle of Man by means of the large Nansen and shear-nets (with two hauls of a "weight-net") used on the S.Y. "Runa," in April, 1913. These hauls were made with the object rather of collecting considerable quantities of the macro-plankton than for quantitative estimation; so, with the exception of the Decapod larvae, only a qualitative survey has been attempted. As both the large Nansen and the shear-net are of coarse-meshed material comparatively few of the smaller organisms were retained. The weight-net was an ordinary tow-net, equipped with embroidery canvas instead of silk, which was sunk by a heavy weight to a few feet from the sea-bottom, and towed very slowly. It proved very efficient for the capture of Crustacean larvae. The large Nansen net (1 metre in diameter at mouth) was invariably used as a surface tow-net in the customary fashion. The shear-net (of embroidery canvas, mouth 1 metre square) was, as usual, worked at an average depth of 10 fathoms. The bottles here reported on contained, therefore, two kinds of material; a series of surface gatherings taken in a large coarse net, and a series of gatherings also made with coarse nets at depths from 8-12 fathoms.

I may now give a few notes in regard to the smaller organisms found associated with the Decapod larvae.

Diatoms.

Coscinodiscus occurred in abundance in almost every netting, and *Biddulphia* was nearly as common, but all other diatoms, with the exception of *Chaetoceras*, were absent from the coarse nettings. The latter was taken in moderate profusion by the surface net only.

Copepods.

Acartia clausi occurred with greatest persistence, and was found in all but a few shear-nettings, but it was run very hard by *Pseudocalanus elongatus*, which rarely failed to appear. Several forms were nearly as common as these two. *Metridia lucens*, *Centropages hamatus*, *Temora longicornis*, and *Calanus finmarchicus* were only absent in a few of the surface gatherings, but of all the Copepods, only *Calanus* appears to swim deep enough to be caught in any abundance by the shear-net. Other Copepods of rarer occurrence were *Anomalocera patersoni*, *Paracalanus parvus*, *Oithona similis*, and *Candacia armata*. *Monstrilla* was taken once in the Calf Sound, in the agitated water of which unusual forms such as this are occasionally found.

Other Forms.

Ceratium (mostly *tripos* and *intermedium*) was found in a few gatherings; *Medusoids* occurred in both surface and deep nets; *Sagitta bipunctata* was found (as usual) in large numbers in the deep nets and sparsely in the surface net; *Tomopteris* was taken twice in the surface net; *Podon* and *Evadne* were present in a few surface gatherings. *Oikopleura* is rarely absent from any gathering.

Larval Forms.

As one of the principal objects of the examination of these catches has been the identification of the Decapod Crustacean larvae contained in them, these will be dealt with in detail below, and the various other larval forms passed over with a note of their occurrence.

Veliger larvae of Gastropods occurred in the surface nets at intervals in the irregular fashion characteristic of plankton organisms.

Polychaet larvae were similarly distributed, but more frequently found.

Fish eggs were abundant in nearly all the gatherings, whether surface or deep, but the larval fish were rarely found above a certain depth, and were almost confined to the shear and "weight" nets.

Echinoderm larvae were of infrequent occurrence; the Brachiolaria occurred in three hauls, the Pluteus in two, and once only a post-larval stage of an Echinoid was taken.

Crustacean larvae were abundant in every netting.

Balanus nauplii seem to be present in enormous numbers at all depths.

Copepod nauplii, larvae, and young stages were found in very many of the surface gatherings, but very few of the deep ones.

Decapoda.

We now come to Decapod larvae, which show interesting features in their vertical distribution. By far the most abundant larva was the zoea (in various stages) of *Hyas araneus*. This occurred in thousands in some of the surface catches, but it is interesting to note that it

was only sparsely represented in deeper nets. The same applied—in a modified way—to *Pandalus montagui*, but with most of the other larvae the reverse was the rule. In consequence the deep nets usually contained a variety of forms, and the surface net an almost pure gathering of *Hyas*. The same fact has been noticed in the catches now in course of collection (April, 1914), and it is a very common thing when examining living collections to see many little black specks (the colour of *Hyas*) in a surface netting, which are replaced by red ones (the colour of *Eupagurus*) in a deeper gathering.

Eupagurus is one of the most typical and abundant of the deeper forms, and, in fact, is not often seen in a surface gathering. This fact possibly accounts for the difficulty experienced in rearing these larvae in the laboratory. In the statement on Decapod larvae in the 1912 Report, I noticed that *Eupagurus bernhardus* seemed to be almost exclusively present in the spring and its fellow, *E. prideauxii*, in the autumn. The same is borne out (as far as the former species is concerned) by the present material, which contains only *E. bernhardus*, and another Eupagurid, of whose identification I am in doubt.

Portunus puber was tolerably common in the surface nettings only, and *P. depurator* turned up occasionally.

The following is a list of the Decapod larvae found. That the list is not longer is probably due to the fact that the deeper nets, which are most effective for catching these larvae, happened to be comparatively seldom applied in the routine of plankton investigations during this particular season.

Hyas araneus ....April 7th, 8th, 10th, 11th, 12th, 14th, 15th, 17th, 18th, 21st.

Portunus puber	,,	7th, 11th, 14th, 17th, 18th, 21st.
P. depurator	,,	11th, 21st.
Corystes cassivelaunus...	,,	11th, 17th, 18th, 21st.
Pilumnus hirtellus..... ...	,,	7th, 8th, 14th, 15th, 21st.
Galatea sp.	,,	7th, 8th, 11th, 12th, 14th, 15th, 17th, 18th, 21st.
Eupagurus bernhardus..	,,	7th, 8th, 10th, 11th, 12th, 15th, 17th, 18th, 21st.
Eupagurus sp.	,,	7th, 21st.
Munida rugosa	,,	7th, 8th, 21st.
Pandalus montagui	,,	7th, 8th, 11th, 12th, 14th, 15th, 17th, 18th, 21st.
P. brevirostris	,,	17th, 21st.
Crangon sp.	,,	7th, 8th, 14th, 21st.
Nephrops norvegicus	,,	7th, 8th, 21st.
Other Macrurans	,,	7th, 14th, 15th, 21st.
Euphausids	,,	7th, 11th, 12th, 14th, 15th 17th, 21st.

The various larval stages of the above species occur in such apparent confusion in the same gatherings that there seems no object in enumerating them. There is no logical succession, as one often catches earlier stages of the same animal on later days than the older stages have been caught.

ON THE DRIFT OF SEWAGE IN THE DOVEY ESTUARY IN RELATION TO THE MUSSEL BEDS.

By Fred. W. Durlacher,
University College, Aberystwyth.

(With Chart.)

In all, I paid four visits to Aberdovey, each time staying two days, except on the first occasion, when I only stopped a few hours for a general look round. On going down to the wharf on that day, two or three hours after high tide, the presence of the sewage in the neighbourhood was most evident; but I shall return to the conditions at the sewer outfall later.

I started actual observations with Captain Lewis the following week, on Friday, 31st October, 1913. Each day before commencing work with the floats we made a rapid round in the launch of several stations I had fixed beforehand as likely to be most interesting as regards salinities, temperatures, &c., and we endeavoured to get readings at those various spots, which I have marked on the map, within as short a period as possible, while conditions were fairly uniform. I have dealt with the hydrographical readings separately.

The floats we used were simply laths from a venetian blind, to which a small stick and flag were attached, weighted at one end with a stone of sufficient size to keep the whole thing upright. Such floats drew about 2 ft. 6 ins. of water, and were not likely to be much affected by the wind.

I will now deal in order with the results obtained under the different sets of conditions.

October 31st.—Spring tides. Wind, W.S.W. strong. Frequent severe squalls. Three-and-a-half hours after high tide we released two floats at a point opposite the sewer, and about 20 yards from its mouth. This was really too far out, but we wanted to give the floats every chance of clearing the wharf. As a matter of fact, both skirted the piles very closely, and took a line in direct continuation of the line of the pier, as shown on the map, eventually touching the ground at the point shown. Current running about $1\frac{7}{8}$ miles per hour.

November 1st.—Spring tides. Wind, S. light. Speed of current $2\frac{1}{8}$ miles per hour. A float and a bottle were released on $2\frac{1}{2}$ hours' ebb somewhat closer in than on the preceding day, at a point where the stream of sewage would likely be deflected. Both made straight for the wharf where they eddied about around the piles for 15 minutes or so, eventually getting free, and taking the same line as before, and going aground on the same spot. While watching these floats, I noticed a little further up the shore the two I had released the day before, which, no doubt, had been carried up the river by the flood, and brought down again by the ebb. This point seems to be of importance, and I will refer to it again in my summary.

November 5th.—Neap tides. Wind, W.N.W. moderate. Speed of current about $\frac{1}{2}$ mile per hour. We released a float on the flood tide $1\frac{1}{4}$ hours before full. It passed within 100 feet of the wall of the Literary Institute, and about the same distance from Penhelyg Police Station. The stream from the sewer was quite noticeable, there being evidently some oily matter present; the gulls, too, generally afford a good indication as to its whereabouts. Opposite Penhelyg the float was making but very little progress, the tide being by this time about slack, and we abandoned it.

November 6th.—Neap tides. Wind, S. moderate. We dropped a float after the flood had been running an hour. It passed about 60 feet off the end of the Literary Institute, and 150 feet off Penhelyg Point, whence it stood out to the south-east, and took a line up the main channel, going aground at the spot indicated on the map, the time occupied from the mouth of the sewer being $1\frac{1}{2}$ hours. No doubt, with the rising tide, the float would have eventually proceeded further, but we were obliged to leave it.

Speed of current 540 yards per hour.

November 26th.—Spring tides. Wind, W.N.W., fresh breeze. The float was dropped on the flood tide two hours or so after turn. It followed practically the same line as on the 6th November, as far as Penhelyg, but there, instead of standing out so far to the South, took a line about 200 yards outside Trevri, in practically a due easterly direction.

November 27th.—Spring tides. Wind, S.W. light. We released the float as soon as the flood tide began to move, i.e., at 3.30. It passed within 20 yards of the end of the Literary Institute, and at 3.55 passed within 10 yards of Penhelyg Point. Its progress past Penhelyg was very slow, 20 minutes were occupied in covering 100 yards. Opposite Penhelyg tunnel, about 30 yards from the shore, it was moving somewhat faster, but owing to the failing light we were unable to follow it further. Captain Lewis felt certain that it would have remained close inshore as far as Trevri. Time from sewer to Penhelyg tunnel 50 minutes.

Appended is a table showing the various sets of conditions I was able to work. At springs I worked both ebb and flood, at neaps only flood tides. I feel sure, however, that the ebb of neap tides would have given me identically the same results with the floats as already stated.

SPRINGS.

Date, 1913.	State of tide.	Wind.	Speed of current.
Oct. 31st.	$3\frac{1}{2}$ hours ebb.	W.S.W. strong.	$1\frac{7}{8}$ miles per hour.
Nov. 1st.	$2\frac{1}{2}$ hours ebb.	S. light.	$2\frac{1}{8}$ miles per hour.
Nov. 26th.	2 hours flood.	W.N.W. fresh breeze.	1520 yards per hour.
Nov. 27th.	1 hour flood.	S.W. light.	About $\frac{1}{2}$ mile per hour.

NEAPS.

Nov. 5th.	$4\frac{1}{2}$ hours flood.	W.N.W. moderate.	About $\frac{1}{2}$ mile per hour.
Nov. 6th.	1 hour flood.	S. moderate.	540 yards per hour.

I shall now give the conclusions to be drawn as to the conditions generally.

Captain Lewis tells me that during the winter the sewage pipe is permanently open, this being thought the most satisfactory way of dealing with it. I have seen it stated in Dr. Bulstrode's report on mussel contamination, and in Dr. Johnstone's report recently, on the authority of the local officials, that the flow of the sewage is such, that on a flood tide it is carried over to the south side of the river, and then out to sea. This is obviously *not* the case. The direction as far as Penhelyg is close to the north shore, and directly over the mussel beds. At Penhelyg, on a rising tide, there is a big eddy caused by the projection of the point, which throws the water back, and the floats remain stationary for some time. What happens subsequently depends chiefly, so far as I could judge, on the state of the tide. If the tide is fairly high, and the current running strongly, the floats will follow the bed of the river, and as the amount of water diminishes, so the line taken will be nearer inshore. It seems to me likely that a fair amount of sewage gets

deposited beneath the eddy at Penhelyg, where there is a deep pool from which mussels are taken.

As regards ebb tides the flow of the sewage is bound to be all round the wharf, whatever the wind, and it subsequently skirts the beach. You will notice that on November 26th, with the wind W.N.W., the drift of the floats was still close inshore. I am of the opinion that, at any rate at neap tides, the greater amount of sewage does not get carried out to sea at all, but moves up and down within the bounds shown on the map. That this is so to a certain extent, is shown by the fact I mentioned earlier in the report, of my finding the two floats at practically the same spot where they had gone aground the day previous.

If the sewage is liberated on the ebb, the conditions about the wharf and along the beach must be particularly objectionable in summer, and it is easy to understand the authorities releasing it on the flood when the town is full of visitors. Even with the small winter population the conditions are fairly bad, and on my last visit I could see the sewage on the sand about the pier at low tide, within 20 yards of where two or three men had their boats moored raking mussels. I think it is only fair to say I could see no trace of it along the shore, West of the pier; nevertheless, it is particularly evident that mussels fished in the vicinity of the wharf are unfit for human consumption.

The mussels this year are not very plentiful, the average take being about one-half to three-quarters of a bag a tide per man. Those which I saw in one of the men's boats were of very good size. As a rule six to eight boats were generally to be seen at low tide between the wharf and Penhelyg.

Hydrographical Readings.

Some 60 hydrometer readings were taken between October 31st and November 27th, but as seven stations were tested, the actual number of readings per station proved too few to establish anything but the very broadest generalisations.

During the four weeks of observations the climatic conditions varied greatly, particularly with regard to the quantitative distribution of rainfall. The funnel-like shape of the estuary is to some extent broken by the northward projecting mass of marsh, sand, &c., capped by Twyne Bach. This projection may cause some considerable ponding and less direct circulation in the South of the area (see map for position of larger cockle bed). The northern portion of the estuary, i.e., the major river area appears to have strongly marked ebb and flood currents and the mixing of fresh and salt water is both rapid and complete.

The area showed very great differences in salinity, varying from a specific gravity minimum of 1·0048 at the wharf on Thursday, November 27th, on slack tide at 3.30 p.m. to specific gravity maximum of 1·0260 at the same station on Saturday, 1st November, on full flood tide at 10.0 a.m. This particular variation from slightly brackish to heavily salted water is an unusual one, and was largely due to the rainfall distribution immediately precedent to these dates, e.g., the rainfall as registered at Aberdovey itself was 0·77 inches for the week preceding November 1st, and upwards of $1\frac{1}{2}$ inches for the week preceding November 27th, while the differences in the area marking the gathering ground of the Dovey were much in excess of this.

The general changes in salinities are more or less in accordance with the particular estuarine conditions which

prevail, e.g., is dependent upon strong ebb and flood. Of the seven stations taken (see map), the greatest change was recorded at station No. 3, but here the conditions are to some extent abnormal, inasmuch as a brook enters the estuary from the North, immediately in the vicinity of this station.

The effect of flood does not appear to be felt in the estuary for at least one hour after it has been running outside the bar, the strength of the river current being sufficient to neutralise its effects. There appears to be a fairly well marked banking up of fresh water on turn of tide.

The chart as it is here reproduced shows the present (December, 1913) distribution of river channels, which are continually changing. In consequence of these changes there are distinct indications that Trevri (Station 7) is now in the nature of a back-water, and often contains salter water than its position appears to warrant.

It was almost impossible to determine the differences in salinity in the area consequent on the change from neaps to springs, particularly so as the stations were all perforce chosen to the North side of the estuary.

Hydrographical Readings (Tabulated).

October 31st.—Springs; high tide, 9.5 a.m.; observations begun 12.30 p.m.; wind, W.S.W. strong.

Stations.	Temperature of Water.	Specific Gravity.
1. Aberdovey	11·6	1·0245
2. Afon Leri	11·4	1·0243
3. Wharf	11·6	1·0235
4. Literary Institute	11·6	1·0240
5. Police Station	11·6	1·0236
6. Junc. of Trerddol and Main Stream	11·6	1·0240
7. Trevri	11·8	1·0230

November 1st.—Springs; high tide, 9.30 a.m.; observations commenced on top of tide; wind, S. light.

Station.	Temperature of Water.	Specific Gravity.
1.	12·2	1·0265
2.	11·8	1·0265
3.	12·2	1·0260
4.	12·2	1·0265
5.	12·2	1·0262
6.	12·2	1·0262
7.	12·2	1·0260

November 5th.—Neaps; high tide, 1.0 p.m.; wind, N.N.W. moderate.

Time of observation.	Station.	Temperature.	Specific Gravity.
10.0 a.m.	1	11·1	1·0213
10.5	2	10·7	1·0186
10.15	3	10·6	1·0185
10.20	4	10·7	1·0195
12.0 noon	Do. 2nd reading.	11·2	1·0259
11.0 a.m.	5	11·1	1·0229
11.15	Do. 2nd reading.	11·4	1·0242
11.5	6	11·4	1·0244
11.10	7	11·0	1·0220

November 6th.—Neaps; high water, 1.45 p.m.; wind, S. moderate.

Time of observation.	Station.	Temperature.	Specific Gravity.
9.45 a.m.	1	9·5	1·0150
10.0	2	9·3	1·0125
9.30	3	9·1	1·0110
10.35	4	9·3	1·0125
10.50	5	9·6	1·0133
11.5	6	10·0	1·0155
12.15 p.m.	7	10·1	1·0195

On this date owing to an accident to the launch we were obliged to row, the observations were thus taken at wider intervals than usual.

November 6th, afternoon.—Neaps; high water, 1.45 p.m.; wind, calm.

Time of observation.	Station.	Temperature.	Specific Gravity.
4.15 p.m.	1	9·5	1·0230
4.0	2	9·4	1·0135
3.50	3	10·2	1·0211
3.40	4	9·8	1·0175
3.35	5	10·6	1·0215
3.30	6	9·4	1·0132
3.20	7	10·3	1·0206

November 26th.—Springs; low water, 1 p.m.; wind, W.N.W., fresh breeze.

Time of observation.	Station.	Temperature.	Specific Gravity.
1.0 p.m.	1	9·2	1·0098
between 12 and 1 p.m.	3	9·2	1·0078
	4	9·2	1·0080
12.0 noon	5	9·2	1·0072

November 26th.—Springs; wind, W.N.W.

Time of observation.	Station.	Temperature.	Specific Gravity.
3.20 p.m.	1	9·1	1·0107
3.15	3	9·2	1·0075
3.55	Do. 2nd reading.	9·2	1·0150
3.25	4	9·1	1·0107
4.0	Do. 2nd reading.	9·2	1·0140
3.30	5	9·2	1·0090
4.5	Do. 2nd reading.	9·3	1·0170
4.15	7	9·2	1·0120

November 27th.—Low water, 1.30 p.m.; wind, S.W. light.

Time.	Station.	Temperature.	Specific Gravity.
11.20 a.m.	1	9·3	1·0200
12 noon	Do. 2nd reading.	9·2	1·0160
11.15 a.m.	3	9·3	1·0190
12.10 p.m.	Do. 2nd reading.	9·1	1·0142
11.10 a.m.	4	9·2	1·0187
12.15 p.m.	Do. 2nd reading.	9·1	1·0136
11.5 a.m.	5	9·2	1·0177
12.25 p.m.	Do. 2nd reading.	9·1	1·0130
11.7 a.m.	6	9·3	1·0190

November 27th, afternoon.

Time.	Station.	Temperature.	Specific Gravity.
3.5 p.m.	1	9·1	1·0085
3.25	2	9·1	1·0048
3.30	4	9·0	1·0060
3.35	5	9·0	1·0057

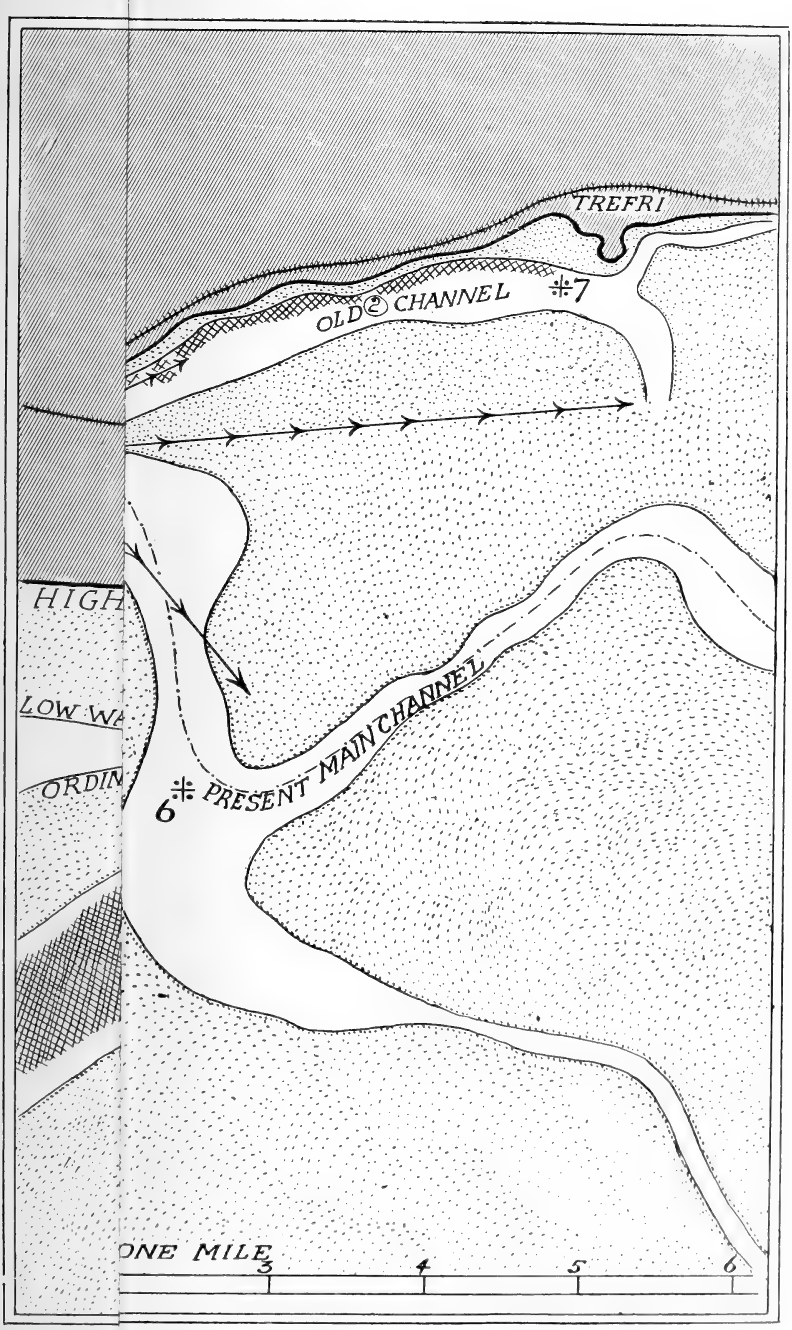
Explanation of the Chart.

The Chart has been copied in general from the 6-inch Ordnance Maps of the District, but the present (December, 1913) situations of the banks and channels are represented instead of those given on the Maps.

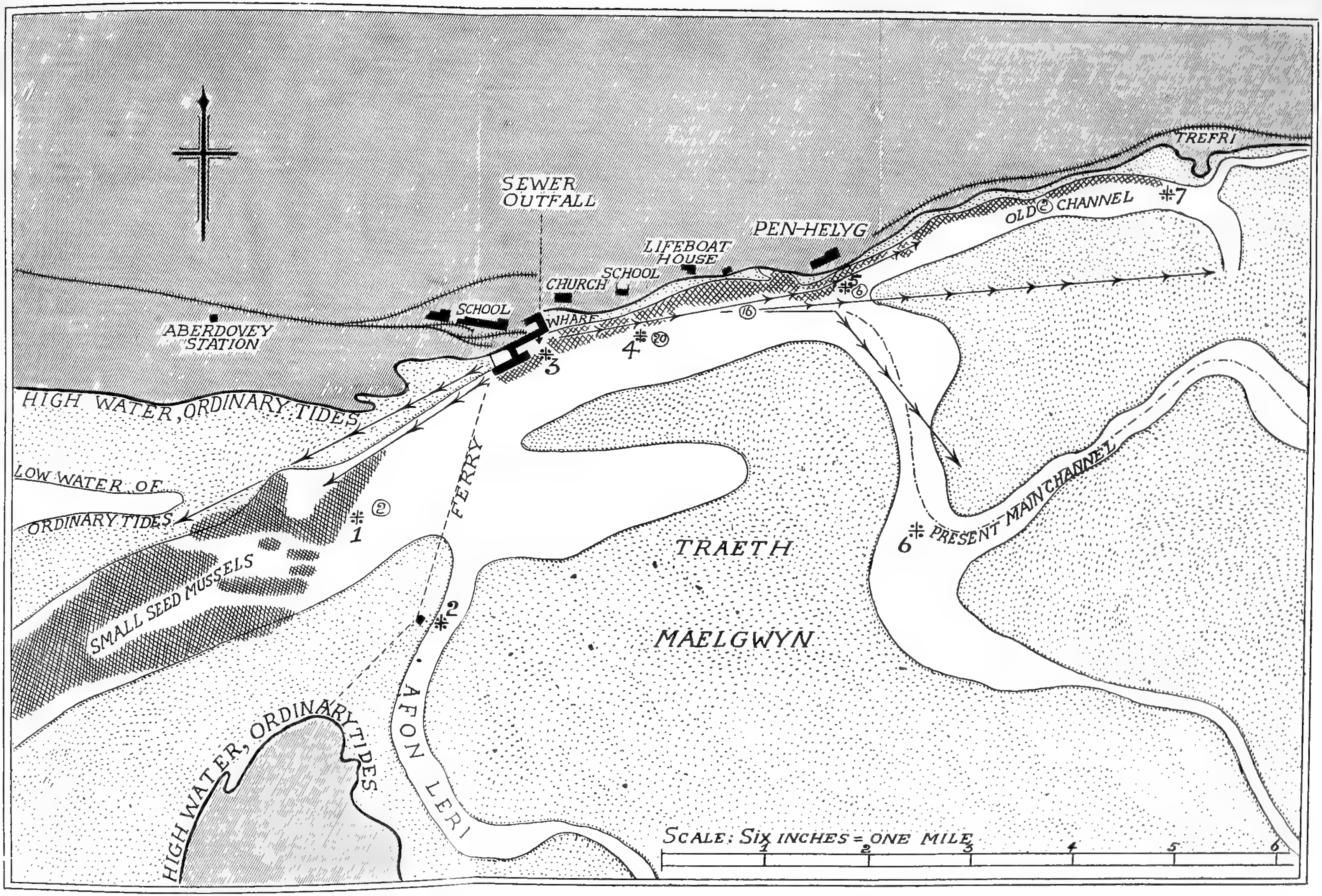
The directions taken by the floats are indicated by the straight lines and arrows. The float was liberated in each case at the beginning of the line and abandoned at the portion marked by the last arrow-head.

The stations where hydrographical observations were taken are denoted by numbered symbols, thus: *2.

The positions of the various mussel beds are shown on the Chart by cross hatchings.


TREFRI
OLD (2) CHANNEL
7
HIGH
LOW WA
ORDIN
6
PRESENT MAIN CHANNEL
ONE MILE
3
4
5
6

er.



Estuary of the Dovey showing the mussel beds and drift of surface water.

ON THE DRIFT OF SEWAGE IN THE ESTUARY OF THE MAWDDACH IN RELATION TO THE MUSSEL BEDS.

By Fred. W. Durlacher,
University College, Aberystwyth.

(With Chart.)

My observations at Barmouth extended over a period of 10 days, and the methods followed were precisely the same as at Aberdovey.

Possible sources of contamination are the two main sewers, whose positions and those of the mussel beds, are shown on the accompanying map; the privies on the quay, emptying directly into the water or on to the sand beneath; and five or six drains which discharge from as many houses on the cliff at Aberamffra. Of these there need scarcely be any doubt that the first sewer, situated a mile or so North of the harbour, can be neglected. During my stay the weather was too rough to allow of a practical verification by means of floats of the direction of the drift from these pipes; nevertheless, it can be taken as practically certain that the flood tide carries the sewage away towards the North, and the strong flow out of the estuary prevents any sewage entering the River on the ebb.

The tidal scour of the estuary is very strong, the speed of the flow at springs beneath the iron railway bridge being about 5 miles per hour, while the flow over the mussel beds at Aberamffra at similar periods is from 2-3 miles per hour. At neaps this rate is reduced by about one-half.

Results of Drift Experiments.

April 14th, 1914.—Neap tides: fresh westerly breeze. A float released at half-flood opposite the buoy marking the sewer outfall passed between the 7th and 8th piles of the wooden railway bridge, and 100 yards off Coes Faen. It then stood out towards the south shore. Another float dropped close inshore opposite the drains from the houses at Aberamffra was carried some yards down river by the eddy, against the set of the tide, then turned and skirted the shore a few yards out. It remained close inshore opposite Aberamffra, and passed 50 yards out from Coes Faen, in the direction of the cockle beds.

Afternoon.—Ebb tide. A float released after 1½ hours ebb close inshore, opposite drains at Aberamffra, went ashore 20 yards lower down.

Half-an-hour later a float, dropped opposite the sewer buoy, took a direct line for the Point of Ynys-y-Brawd, where it eddied around, and finally went aground.

April 6th.—Fresh westerly breeze: flood tide. The float dropped opposite the sewer buoy, on half flood, passed just inside outer line of buoys marking the channel above and below the bridge, and 30 yards off Coes Faen.

April 7th. Fresh W.N.W. breeze: ebb tide. A float, released about 15 yards outside the sewer buoy on last of ebb, came inshore as far as the point of Ynys-y-Brawd, went 30-40 yards up river with the eddy of the island, and opposite the sewer buoy remained practically stationary, the tide being slack.

Afternoon.—First of flood. From the sewer outfall the float took a somewhat zigzag course. It passed first just inside the inner of the buoys marking the channel below the bridge, under the furthest arch of the iron railway bridge, inside the outer of the buoys marking the

channel above same, 20 yards off Aberamffra Quay, practically touched Coes Faen, and then stood out to the South. About $1\frac{1}{2}$ hours later the float was seen aground on the rocks at Coes Faen, doubtless having been carried round by the eddy off the sandbank at that point.

April 8th.—Fresh N.W. breeze: ebb tide. After about 4 hours' ebb a float was dropped 15 yards outside the sewer buoy. It ran about 150 yards straight down towards the bar, and then crossed to the further bank, continuing its course very close inshore.

Another float released one hour later passed close inshore past the beacon on the point of Ynys-y-Brawd, and continued its way towards the bar about 10 yards out.

April 9th.—Springs: strong S.S.W. breeze: ebb tide. A float released on the ebb, about 1 hour earlier than on April 8th, gave practically the same results, the course followed being somewhat further out from the shore.

Another float was dropped over the quayside at half-ebb (10.15 a.m.) opposite the drain from the privies. At low tide this was found high and dry, about 10 yards out close to the spot of its release. At about 5 p.m. it was refloated by the flood tide, and stood out into the main channel, passing between the 7th and 8th piles of the wooden railway bridge.

Afternoon.—The float dropped at 4.30 p.m., at half-flood, passed under the furthest span of the iron railway bridge. From this point it was lost sight of, but we believed that it stood out towards the south shore in the direction of Fegla Fawr.

Conclusions as to the Drift of Sewage.

The sewer which discharges into the harbour has its outfall marked by a buoy which is placed about 400-500 feet to the East of Trwyn-y-Gwaith, and originally was

provided with a flap which was intended to prevent the escape of sewage at other than ebb tide. This flap, so I was told, became detached some years ago, and in addition a number of pipes have worked loose, become unbolted or broken, so the sewage now escapes at all states of the tide, and at a point some 40 feet nearer shore than the point marked by the buoy. I also heard that one of the pipes had even been standing on end, and had to be removed, as it was a danger to navigation. I should, therefore, have dropped my floats 40-50 feet closer inshore, but this was impossible owing to the danger of the launch going aground. The results obtained on ebb tides showed that at neaps the sewage does not get carried down to the bar, but is held in the eddy off Ynys-y-Brawd, moving up and down between the island and the sewer outfall till turn of tide. The sewage at such periods can be seen at the surface in the area marked, and also lying about the shore of the island near the beacon. At spring tides the floats were carried down towards the bar and out to sea.

A lavatory with three privies on the quayside is another contaminating influence in this area, which dries out completely at low tide. Any sewage entering here is likely to accumulate, and probably only gets carried away by a strong flood tide. On flood tides the direction taken by the floats after reaching the railway bridge depends on the state of tide and the amount of water in the estuary. The earlier the state of tide the closer inshore is the drift likely to be. At no state of the tide though did the floats pass directly over the mussel beds between the bridge and Aberamffra harbour. Considering the distance of these beds from the sewer outfall it seems probable that a good deal of the contamination of these mussels is due to the drains from the houses on the cliff which empty directly on to the beds. Here, too, at low

tide, I have seen sewage lying on the shore. The only spot which seems at all safe at present for purification tanks is Penrhyn Point or its neighbourhood. A number of stones are thrown up on this part of the shore, which is in the nature of a storm beach, and if tanks were constructed, some method would have to be devised to keep them free from such stones. Although there is no tidal set in this direction, nevertheless, with a N.W. wind surface water would be blown across from the vicinity of the sewer outfall.

It seems as if, quite apart from mussels, some repairs will have to be carried out on the harbour sewer pipe, which is in a bad state. If, when this is done, several more lengths could be added, the flap refixed, and another method found of draining the houses on Aberamffra cliff, the mussels at Aberamffra should be rendered absolutely safe.

Hydrographical Readings.

The hydrometer readings do not call for any special comment, being fairly consistent and presenting nothing abnormal. As at Aberdovey, the effect of the flood is not felt in the estuary for one hour or more after it has been running outside the bar, and there is a considerable banking up of fresh water on the turn of the tide.

April 6th, 1914.—Neaps; first high tide, 5.0 a.m.; readings taken from 3.10 p.m. to 3.20 on half flood; fresh Westerly breeze.

Station.	Air Temperature. Readings taken 10 a.m.	Water Temperature.	Specific Gravity.
2	11·1°C.	9·4°C.	1·0256
3	,,	9·3	1·0256
4	,,	9·4	1·0255
5	,,	9·2	1·0251
6	,,	9·4	1·0240

Readings taken from 5.25 p.m. to 5.40 p.m. on top of flood.

2	11·1°C.	9·0°C.	1·0257
3	,,	9·1	1·0255
4	,,	9·1	1·0255
5	,,	9·1	1·0256
6	,,	9·3	1·0255

April 7th.—First high tide, 5.45 a.m.; readings taken from 11.15 a.m. to 11.30 a.m.; fresh W.N.W. breeze.

Station.	Air Temperature. Readings taken 10 a.m.	Water Temperature.	Specific Gravity.
1	12·8°C.	8·4°C.	1·0123
2	,,	Tide too low	—
3	,,	8·3	1·0126
4	,,	8·1	1·0084
5	,,	8·3	1·0070
6	,,	8·2	1·0060

Readings taken from 2.15 to 2.30 p.m. on first of flood.

1	12·8°C.	9·0°C.	1·0093
2	,,	Tide too low	—
3	,,	8·8	1·0082
4	,,	8·9	1·0054
5	,,	8·6	1·0072
6	,,	8·8	1·0047

Readings taken from 3.45 p.m. to 4.5 p.m.

1	12·8°C.	9·0°C.	1·0253
2	,,	9·0	1·0250
3	,,	9·0	1·0246
4	,,	9·1	1·0245
5	,,	9·0	1·0242
6	,,	9·0	1·0245

April 8th.—First high tide, 6.32 a.m.; readings taken from 10.20 a.m. to 10.40 a.m. on two-thirds ebb; fresh N.W. breeze.

Station.	Air Temperature. Readings taken 10 a.m.	Water Temperature.	Specific Gravity.
1	10·6°C.	8·4°C.	1·0213
2	,,	Tide too low	—
3	,,	8·3	1·0210
4	,,	8·3	1·0187
5	,,	8·2	1·0165
6	,,	8·2	1·0162

Readings taken from 11.50 a.m. to 12.10 p.m. on last of ebb.

1	10·6°C.	8·2°C.	1·0145
2	,,	Tide too low	—
3	,,	8·1	1·0148
4	,,	8·0	1·0110
5	,,	8·1	1·0101
6	,,	8·2	1·0095

April 9th.—Springs ; first high tide, 7.14 a.m. ; readings taken from 10.30 a.m. to 10.50 a.m. ; strong S.S.W. breeze.

Station.	Air Temperature. Readings taken 10 a.m.	Water Temperature.	Specific Gravity.
1	13·9°C.	8·8°C.	1·0245
2	,,	Tide too low	—
3	,,	8·8	1·0241
4	,,	8·0	1·0237
5	,,	8·8	1·0235
6	,	9·0	1·0230

Readings taken from 4.5 p.m. to 4.30 p.m. on half flood.

1	13·9°C.	9·3°C.	1·0175
3	,,	9·2	1·0178
4	,,	9·0	1·0165
5	,,	9·1	1·0158
6	,,	9·0	1·0137

April 10th.—First tide, 7.57 a.m. ; readings taken from 12.45 p.m. to 1.5 p.m. ; strong S.W. breeze.

Station.	Air Temperature. Readings taken 10 a.m.	Water Temperature.	Specific Gravity.
1	12·8°C.	9·2°C.	1·0225
3	,,	9·3	1·0210
4	,,	9·2	1·0200
5	,,	9·2	1·0193
6	,,	9·3	1·0180

Readings taken from 3.15 p.m. to 3.30 p.m.

1	12·8°C.	9·8°C.	1·0136
3	,,	9·9	1·0137
4	,,	9·8	1·0118
5	,,	9·8	1·0107
6	,,	10·0	1·0117

Readings taken from 4.45 p.m. to 5.0 p.m.

1	12·8°C.	9·9°C.	1·0139
3	,,	9·6	1·0146
4	,,	9·8	1·0118
5	,,	9·6	1·0135
6	,,	9·9	1·0094

April 13th.—First high tide, 10 a.m.; readings taken from 10.40 a.m. to 10.55 a.m. on first of ebb; moderate Westerly breeze.

Station.	Air Temperature. Readings taken 10 a.m.	Water Temperature.	Specific Gravity.
3	12·8°C.	9·2°C.	1·0262
4	,,	9·2	1·0268
5	,,	9·2	1·0263
6	,,	9·2	1·0266

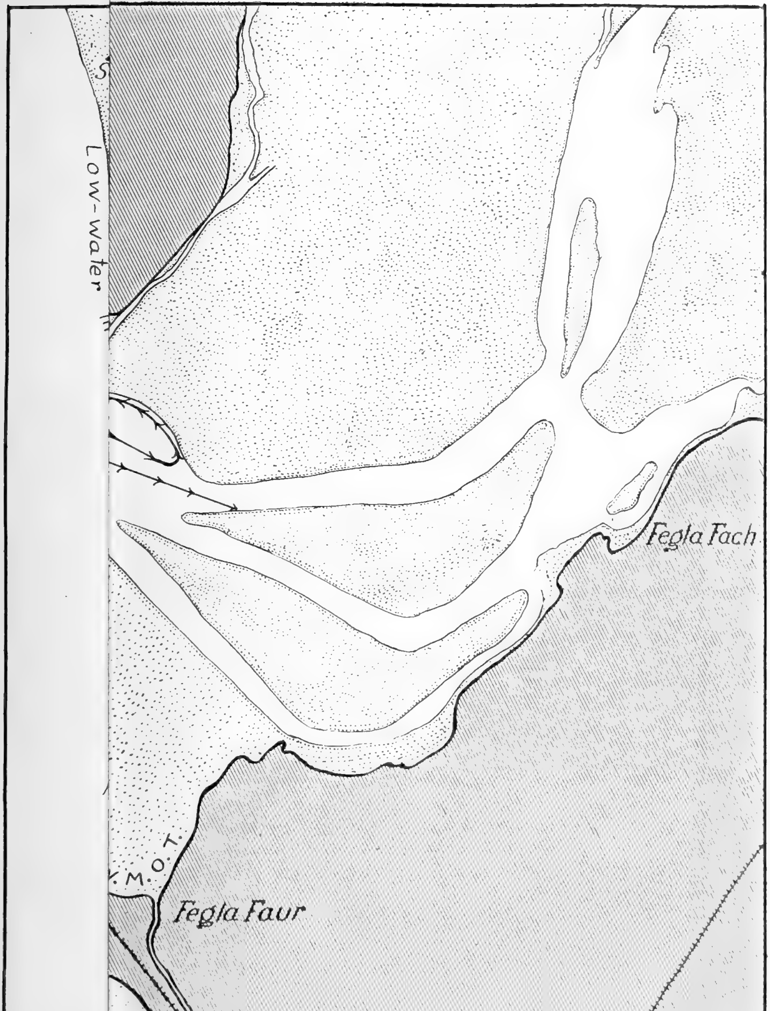
Readings taken from 12.15 p.m. to 12.35 p.m.

1	12·8°C.	9·4°C.	1·0268
3	,,	9·5	1·0268
4	,,	9·4	1·0260
5	,,	9·4	1·0260
6	,,	9·5	1·0262

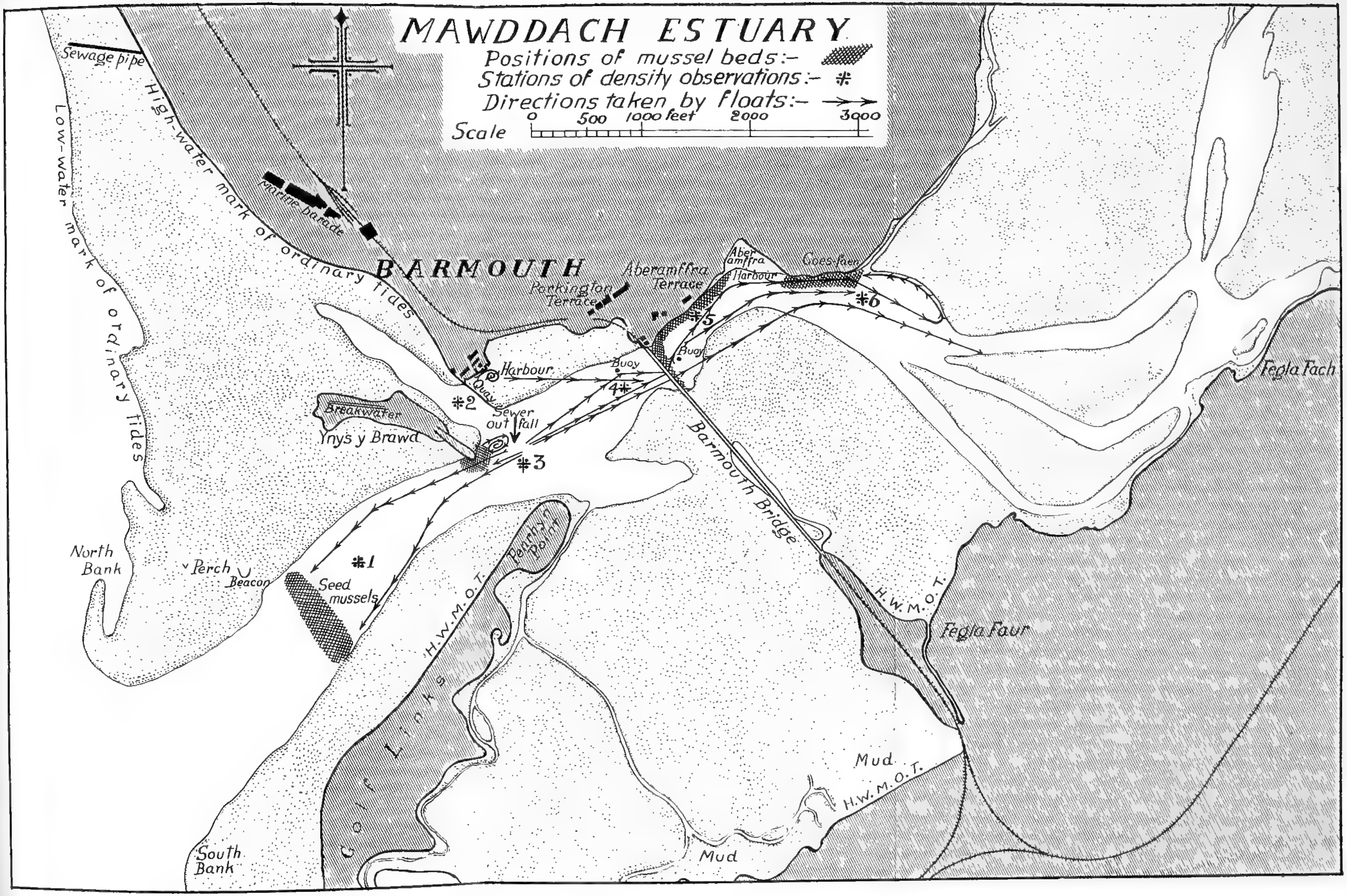
The amount of rainfall for *March* in the district affecting the Mawddach was approximately 6 inches, which is some 200 per cent. of the average for this month.

Explanation of the Chart.

The accompanying Chart has been reproduced from the 6-inch Ordnance Map of the district, with certain additions which are noted on the Chart.



S
Low-water
Fegla Fach
V.M.O.T.
Fegla Faur
O.T.



MAWDDACH ESTUARY
Positions of mussel beds:-
Stations of density observations:- *
Directions taken by floats:-
Scale
0 500 1000 feet 2000 3000
Sewage pipe
High-water mark of ordinary tides
Low-water mark of ordinary tides
Marine Parade
BARMOUTH
Parkington Terrace
Aberamffra Terrace
Aber amffra Harbour
Goes-faen
Harbour
Quay
Buoy
Buoy
Buoy
*2
*3
4*
*5
*6
*1
Sewer out fall
Breakwater
Ynys y Brawd
Barmouth Bridge
North Bank
Perch
Beacon
Seed mussels
Penrhyn point
H.W.M.O.T.
Golf Links
H.W.M.O.T.
Fegla Fach
Fegla Faur
Mud
H.W.M.O.T.
Mud
South Bank

REPORT ON THE EXAMINATION OF VARIOUS MUSSEL BEDS IN LANCASHIRE AND WALES DURING THE YEAR 1913.

With Five Plates.

By Jas. Johnstone, D.Sc.

Contents.

A proposal has been made by the Joint Committee during the present year to obtain a Regulating Order enabling them to supervise the collection and storage of mussels in the estuaries in Cardigan Bay; and in consequence of this proposal inspections of these shellfish beds and analyses of mussels taken from them have been made. I visited the Port Madoc area in May, 1913, and met Mr. Casson and Captain Pritchard who accompanied me in the inspection of the estuary. In June I visited Aberdovey, and in July Barmouth, being assisted on each occasion by Captain E. Lewis, the Fishery Officer in charge of the district. Also, in October, some complaints were received by Dr. Jenkins with regard to the Mussel Beds in the Ribble Channel near Lytham, and he and I visited this area, where I collected samples for analysis. Mr. Scott visited Roosebeck in October.

(1) The Mussel Beds at Port Madoc. (Plate I.)

These particular beds have been attended to from time to time. I first visited Port Madoc in November, 1906, when I took samples and made analyses; and a further inspection was made by Dr. Bulstrode and myself in 1908. No report, however, has yet been made with regard to this area. The mussel fishery is not one of great importance, and those engaged in it work, for the most part, casually, in the intervals of other kinds of employment, or as a temporary change from idleness, or want of employment. The industry is not an organised one, as it is at Morecambe or Conway, and it has hardly been necessary to report upon it. But from the point of view of the closer regulation of the whole shellfish industry of Cardigan Bay an inspection became necessary during the present year.

Mussels are found over most parts of the harbour at Port Madoc and in the estuary near Borth. The shellfish in the harbour are not large ones, but those found at the bottom of the channel, near Borth, are large and well-nourished fish.

Most of the sewers discharge into the upper parts of the harbour. A certain amount of sewage (No. 1 on the chart) flows down a small stream which enters the harbour well above the lock gates, and to the west of the latter. This stream also receives the sewage discharging from the Chapel Street sewer, and representing a population of about 2,000 persons. Normally, this sewage flows, at low water, through a small channel in the mud in the upper part of the harbour, but higher up than the Gasworks there is a bye-pass leading into a small brook through which sewage from Outfalls Nos. 1 and 2 may enter the Glaslyn River to the east of the lock-gates. There is another outfall, No. 4, on this side

serving a population of about 200 people, and nearly opposite this, on the Port Madoc side of the harbour, is another outfall, No. 3, serving also about 200 people. Lower down, and nearly opposite to the Ballast Bank, is another outfall, No. 5, from which the sewage of about 380 persons is discharged. Lower down the estuary still, at Amanda Terrace, at Borth, is an outfall, No. 6, which drains an area populated by about 600 people. This was the condition of the estuary, with regard to sewer outfalls, in 1910. Since then a septic tank has been constructed at Borth.

The channel formed by the Glaslyn river below Port Madoc is very shallow, and the depth of water in the harbour is also very little. The bar at the entrance to the channel is a high one, so that there is not much interchange of water between the harbour and the sea outside. For four or five days before and after the lowest neap tides water probably oscillates up and down the channel between the harbour and the bar, and is not really renewed from Tremadoc Bay. For a few tides at about the time of the springs there will be a renewal of the water from outside, but for most of the fortnight between one high spring tide and the next one sewage probably accumulates in the water of the harbour and channel, and is then flushed out during the two or three highest tides of each fortnight. A certain amount of flushing action is probably also produced by heavy floods coming down from the upper parts of the Glaslyn river. Because of these conditions samples of mussels and water taken from harbour and estuary will give very different bacteriological results, according to the state of the tide when the samples are taken. I did not have time to make a complete series of analyses at all states of tide and river flooding, but if mussel cleansing works should

ever be contemplated in Port Madoc channel such analyses would, of course, be necessary.

There does not seem to be any suitable place where such cleansing tanks could be erected in the upper parts of the harbour. The Glaslyn river, to the east of the lock-gates, is polluted by the sewer discharging near Britannia Foundry (No. 4), as well as by the sewage that doubtless flows occasionally down the little brook opening into the river here. There appear to be difficulties in the way of constructing any works on or near the Ballast Bank, though these would not be insuperable to an engineer if cost did not matter. Then, because of the imperfect flushing of the river, between the harbour and Borth, with flood-tide water from the open sea, this part of the channel is also unsuitable. There remains only the plan of putting up a tank lower down than Borth.

Mussels occur here and there in the channel near the rocks called Gareg Goch and Careg Cnwc, and it was suggested by Dr. Bulstrode that the seriously polluted shellfish from the upper part of the harbour might be transplanted to this part of the channel. This general removal of mussels from the harbour and redeposition in the seaward part of the channel could, of course, be carried out by an organisation similar to that set up at Morecambe some years ago, and it would lead not only to a certain amount of purification of the shellfish, but also to an increase in growth. But even here there is risk of pollution in such circumstances as floods in the upper part of the river during low neap tides. Thus the analysis made on 11th April, 1913, showed that the mussels at Gareg Goch were polluted to a less degree than those in the harbour; this was at a time when there was little fresh water in the river. But on 21st April

the opposite state of affairs was observed: the pollution of the mussels at Gareg Goch was greater than that of the mussels from the harbour. This was at a time when there was much fresh water in the river, so that what probably happened was the scouring of the sewage-polluted mud and foreshore of the harbour, and the transport of this contaminated mud to the channel below Borth, thus leading to the pollution of the mussels there. It is to be expected that this would happen frequently.

An analysis of the small mussels growing on the rocks at Gareg Goch and Careg Cnwc was made, and this disclosed a greater degree of pollution than I had expected. However, these rocks are at some considerable distance from the nearest sewer outfall, and the pollution is therefore less serious than the analysis seems to reveal. We may, I think, conclude that if a tank or enclosure could be constructed on the rocks at Gareg Goch and Careg Cnwc, so that it might be filled from the flood tide near its highest level, the water would be reasonably free from contamination. Whether such a tank or enclosure can be built at this place, at a cost commensurate with the object to be achieved, is, of course, a matter for an engineer to consider.

I think there is no doubt that the pollution of the mussels in the harbour at Port Madoc is too serious to be neglected.

(2) **The Mussel Beds at Aberdovey.** (Plate II.)

I visited Aberdovey on 19th June and collected samples of mussels and water for analysis. One sample of mussels was obtained by raking from the bottom of the channel close up to the Pier, at a distance of about 400 feet from the sewer outfall. The depth at the time

of collection was about 20 feet. A sample of water was taken from the same place at the same time. Another sample was taken from the channel close up to the rocks at Penhelyg Point, at a distance of about half a mile from the sewer outfall. The depth of water here was about 18 feet, and the mussels were raked from the bottom of the channel. A water sample was also taken from this place.

The conditions at Aberdovey are not such as suggest contamination, on a superficial view of the estuary. The latter is rather over a mile in width at Aberdovey, so that an enormous volume of water must flow in and out at every tide. This water coming directly in from Cardigan Bay must be very clean. But if the estuary be examined at low water the conditions will then be seen to be such as must lead to most serious pollution of the mussel beds.

The population of Aberdovey varies from one to two thousand persons. The sewage produced is intercepted and discharged by a single sewer, a 15-inch iron pipe, discharging near to the Pier, and the end of which is covered by about 3 feet of water at low water of spring tides. There is no treatment of the sewage, but the outflow is intermittent. It lasts for about half an hour at about half-flood tide, and for the remainder of twelve hours the sewage is banked up in the pipe by a penstock. The object of this arrangement is to prevent the fouling of the bathing place, which is situated to the west of the pier. The direction of flow of the sewage is said to be such that it is carried over towards the south side of the estuary and then out to sea. If the arrangement for liberating the sewage is strictly adhered to, and if the direction of flow is that stated above, it is difficult to see how the mussels in the estuary can be fouled. Still,

one must assume that, at other times than the holiday season, when there is no bathing in the estuary, the sewage *may* be liberated at any state of the tide that permits of the discharge; and, further, that in varying conditions of tides and winds and sea the direction of flow *may* be otherwise than that stated.*

At low water the width of the open channel is not great. It varies from about 600 to 700 feet between Aberdovey and the bar, and from about 600 to 300 feet between Aberdovey and Trefri. The depth of water is also very little. At low water it is not much more than about one fathom on the bar, and the greatest depth in the channel is five fathoms, about half a mile west from Aberdovey. Between the bar and the pier the average depth at low water is only about two fathoms, while between Aberdovey and Trefri it is, on the average, less than one fathom at low water of spring tides. The volume of water in the channel is therefore not very great, and near low water of even ordinary tides any discharging sewage may very easily pollute the water in the shallow channel north from the pier.

The mussels are found in the channel both east and west from the pier, and they may be obtained in close proximity to the sewer outfall. East from the pier they are mainly found near the north side of the channel, where the bottom is hard. These mussels are of fair size and good quality. West from the pier they are small and badly nourished. It is proposed to transplant mussels from the seaward side of Aberdovey to the channel at Penhelyg, and further to the east.

There can be no doubt that the mussels from the estuary of the Dovey are polluted so grossly that they ought not to be used as human food without some preliminary purification. They are bacteriologically worse

*See the Report, by Mr. F. W. Durlacher, in this volume, p. 425, on the Drift of Sewage in the Estuary of the Dovey.

than any Lancashire or Welsh mussels, with the exception of a sample which I report on later on—one taken from the Ribble Channel in the full flow of the polluted water containing the sewage of Preston, Southport (probably), Lytham and other towns. The counts of sewage bacteria in the mussels are practically the same in both cases, about 20,000 organisms per mussel. But the pollution at Aberdovey is far more significant, potentially more dangerous one may say, than in the case of the Ribble. In the latter estuary the contamination is remote, and it may be the case (I propose to discuss this question in a later report) that a lengthy sojourn of these bacteria in sea water may have changed their character. But in the case of Aberdovey the mussels may be taken from almost the immediate vicinity of a sewer outfall, so that the contamination is almost an immediate one, and only a very short time may elapse between the discharge of the sewage and its ingestion by the shellfish. In these circumstances the same degree of bacteriological pollution is more serious.

The bacteriological contamination of the mussels taken from the channel at Penhelyg is practically the same as that of the mussels collected from near the sewer outfall. The former ground is only one-half mile distant from the sewer. Now if the discharge of the sewage is regulated as is indicated above, and if the currents in the estuary are as stated, it is difficult to see how these mussels can be contaminated. Yet the contamination in June last was very notable, and we can only conclude that the direction of drift of surface water *may at times* be such that the sewage flows along the northern side of the estuary towards Penhelyg. It is also possible that sewage may flow from the outfall at other times than for one half-hour at half-flood tide—at any rate, the pos-

sibility of this ought to be reckoned with in suggesting any proposals for transplanting mussels from seaward of the pier to the channel at Penhelyg. As far as the observations made up to the present time go, such a proposal cannot be safely recommended, for the site suggested is distinctly within the influence of the sewage discharge. Transplanting, in my opinion, ought to be accompanied by some measures of purification before one can say that it is an operation free from danger to the public health.

The water analyses made on the occasion of this inspection gave encouraging results. It is true that sewage microbes were present in one cubic centimetre of the water sampled, but they were just present, and the degree of contamination was not a high one. The samples were taken towards the end of the ebb stream, when the tide had still about an hour to ebb. Probably, samples taken at about the time of high water would be more distinctly free from pollution. The *rationale* of constructing mussel purification tanks here would be so to make the tank that it would contain the maximum quantity of mussels taken from the estuary during a period of four days during the busiest time of the fishery. The tank should also be so placed that it could be filled with water taken from the estuary at high water of the lowest neap tides, allowing for the reduction of level in the height of these tides that may be due to abnormal conditions of wind; that is to say, it should be ascertained whether a prolonged spell of easterly winds in the estuary causes the tide to rise less high than the height shown on the tide tables, and this should be considered in determining a place for the tank. I do not think that there is any suitable place to the west of the pier where a tank could easily be built, and to the

east of the pier the shore is rather rocky and rises steeply. This, however, is a matter for an engineer's opinion, and, obviously, the main question to be considered is that of cost. Would it be worth while to construct expensive works considering the restricted mussel fishery in the estuary? This is not all, however; even at Penhelyg Point the sewer outfall is only one half-mile away, and it is possible that, with a possibly unregulated (or imperfectly regulated) discharge of sewage, some of the latter *might* reach the tanks. This is a danger which could, perhaps, be anticipated and guarded against by a thorough survey of the estuary with regard to the direction of flow of water at all states of the tide, and in all conditions of weather.

3) The Mussel Beds at Barmouth. (Plate III.)

The estuary of the Mawddach river, like that of the Dovey, is a very considerable expanse of water near the height of the tide. It varies in width from about half a mile to more than a mile. But at low water the channel contracts to a strip of about two or three hundred feet in width, and the greatest depth in it is only about 5 fathoms at low water of spring tides, while here and there the depth is very much less. The depth on the bar is only about $\frac{1}{4}$ to $\frac{1}{2}$ fathom, so that very much the same conditions that we have noted in the case of Port Madoc estuary may also exist here: during low neap tides the flushing out of the estuary from the sea may not be complete. Yet it is the case here (but not at Port Madoc) that the mouth of the estuary is a 'bottle-neck'; for there is a very considerable basin east from Barmouth which is filled at every tide, and the flow through the bottle-neck may be more effective in scouring the channel than one, at first, might expect.

Barmouth has a population which varies from about 2,500 in winter to 5,000 in summer. It is served by two main sewers, one (No. 1) which has its outfall about one mile north from the harbour, and another (No. 2) which has its outfall in the channel close to the harbour. There are also some houses east from the railway bridge which appear to be too low to drain into the sewer discharging by No. 2 outfall, and these are separately drained directly into the estuary. The main outfall (No. 1) consists of three pipes, but two of these appear to discharge surface or storm water only. The outfall from the chief pipe is well below low water of spring tides. The sewage itself probably is carried well out to sea, but there are indications of the backwash of some organic matter in the abundant growth of green algæ on the stones of the beach near the outfall. This sewer serves about half of the population.

The other sewer (No. 2) discharges into the harbour. Its end is marked by a buoy which is placed about 400-500 feet to the east of Trwyn-y-Gwaith. The outfall is always covered at low water of spring tides. Round the outfall the water of the harbour is very noticeably discoloured by the discharge, and there is a strong smell of sewage. This sewer serves about one-half of the population.

Both sewers discharge an untreated effluent.

Mussels are found on the bottom of the channel near the harbour, round the end of the breakwater called Trwyn-y-Gwaith, and in close proximity to the sewer outfall. I was informed that these mussels had been sent to the public markets. There are mussels on the shore near Barmouth Bridge, and on the piers of the bridge itself. There are also mussels on the bed of the channel on the northern side, and from the bridge to

above Aberamfrach Harbour, and on the southern side of the channel opposite the latter place. There are also mussels in the channel seaward from Trwyn-y-Gwaith. I did not see these latter shellfish: they are said to be small and badly-nourished.

Samples were taken from near the quay at the western side of Aberamfrach Harbour, and from the channel close to the beacon on the end of the breakwater at Trwyn-y-Gwaith. These mussels were raked from the sea-bottom. Samples of water were taken from the surface of the channel at Aberamfrach, at the bridge, lower down, and at Trwyn-y-Gwaith.

It is improbable that the mussels in the harbour or higher up can be affected by the sewage from No. 1 outfall. This is a considerable distance away and there are extensive sandbanks, rising to a height of 9 feet above low water of spring tides, between it and the harbour. The ebb tide flowing from off these sandbanks and out from the estuary would prevent the sewage from entering the channel at any state of ebb tide, while on the first of the flood it would tend to drift to the north. If the sewage from all parts of Barmouth could be diverted into this sewer there would be little likelihood of the contamination of the mussels in the channel. But this would be impossible, I believe, without pumping.

As it is, the mussels in the harbour are exposed to immediate and gross pollution from the outfall sewer No. 2. The bacteriological contamination here—about 6,000 intestinal organisms per mussel—is practically the same as in the worst part of the estuary of the Lune at Lancaster; but the pollution is really more serious at Barmouth, for the mussels are very much nearer to the source of pollution. It is too serious, I think, to allow of these mussels being used as human food. The mussels

at Aberamfrach, that is, at a distance of about half a mile from the outfall, did not exhibit such marked pollution on the occasion of this sampling; still, the pollution was far too serious to be neglected. It is probable that, in certain conditions of wind and tide, the difference between these two places, as regards pollution, may not be appreciable. The estuary is narrow and not deep, and the flood stream flows directly from the sewer outfall towards Aberamfrach. It would be wrong, I think, to regard the mussels above the railway bridge as being, on the whole, less seriously polluted than those in the harbour. Dr. Bulstrode, in his last report, suggested the relaying of mussels taken seaward of the bridge in some part of the channel landward of the bridge, but I doubt very greatly whether this would, on the whole, be a safeguard. Certainly, transplanting of the smaller mussels found in the seaward part of the estuary to the upper part would lead to increased growth of the shell-fish, but these upper parts of the estuary are far from being unpolluted.

Transplanting in the Barmouth estuary would, in order that the public health might not be affected, have to be accompanied by some measures for the purification of the shellfish, that is, if it should be found impossible to divert all the sewage into the northern outfall. This I have no doubt would be possible, and the only question to be considered is whether the mussel industry in the estuary is capable of such further development as to justify asking the local authority to face this expense. In the season, November, 1906, to February, 1907, the total value of the mussels despatched from Barmouth was £148. No doubt this value could be increased considerably by well-planned transplantation, but even then the cost of the sewerage scheme and the increased revenue

to a very restricted section of the population of Barmouth would have to be carefully balanced before one could venture to express an opinion as to the desirability of this change. I do not know whether it is possible to hold back the sewage now discharging from No. 3 outfall, by means, preferably, of septic tanks and filter beds, and then to turn out an effluent at some particular state of the ebb tide, so as to avoid the fouling of the upper part of the channel on the one hand, and the bathing grounds on the other. This, also, is largely a question of the same nature as that indicated above. The success of this procedure would also imply the conscientious working of the regulations with regard to the liberation of the sewage.

There remains, now, the question of the practicability of constructing a pond or tank near high water of neap tides, and at some convenient part of the estuary. This is a question which, naturally, would have to be submitted to an engineer before the Committee could satisfy themselves that the suggestion is likely to be successful. It is a matter of expense largely, but the purity of the water which would be used to fill the tank, and also the convenience of the fishermen, would also have to be considered. At first sight, the little island opposite Barmouth, Ynys-y-Brawd, seems to be suitable, but this island consists largely of sand, which is evidently shifted by being blown by the wind. There are breakwaters at either end of it, so that a considerable amount of sea must sometimes be experienced on its windward side. Whether or not it would be possible to make a tank on the landward side, I do not know. It does not seem likely that a tank could easily be made anywhere seaward from the harbour, and although the shore opposite Barmouth, Penrhyn Point, might have

places that would be suitable, there would be the formidable difficulty of conveying the mussels across the estuary during rough weather in the winter months. On the whole, Aberamfrach Harbour seems to be the most suitable place, judging from a preliminary survey of the estuary, which is, of course, all that I have been able to undertake. This place has a muddy bottom, but it might be possible to build concrete walls somewhere in its vicinity, so as to make a tank which would only be filled at high water. I do not know what the approximate cost of this would be; and, of course, the suggestion of any site approved by an engineer would necessarily mean an investigation by means of drift bottles, &c., as well as salinity observations and bacteriological estimations of the impurity of the water at all states of the tide and various conditions of weather, before a definite working scheme could be recommended.

(4) The Ribble Mussel Beds. (Plate IV.)

In consequence of some recent complaints, Dr. Jenkins and I visited Lytham and inspected the mussel bed in the Ribble Channel near there. Although I visited the cockle beds both on the north and south sides of the Ribble estuary in 1907, and the mussel bed at St. Anne's in the previous year, this is the first occasion on which the shellfish in the Ribble channel itself have been examined.

Plate IV. is copied from the latest and most complete chart of the Ribble estuary, that made in 1904 as the result of a survey carried out by Messrs. Barron and Hamer. It shows the channel from Preston to near the sea. The main channel is very narrow and shallow, and it is being "trained" by rubble walls, in the hope that it may break through to the sea and maintain, *via* the

"New Gut Channel," instead of through Pinfold Channel, the former entrance to the Ribble. It will be seen that there is a most extensive tract of sandbanks through which relatively narrow, shifting and shallow channels make their way. These channels receive the sewage from a very large population: Preston, about 120,000 people; the Southport and Birkdale districts, about 55,000; Lytham, about 10,000; Fairhaven and Ansdell, about 4,000; and St. Anne's-on-the-Sea, about 7,000. The Preston sewage is treated by coarse screening, sedimentation and irrigation over about 500 acres of land on a sewage farm, and it is not liberated on the ebb until the level of water in the channel has sunk below the level of the training walls, while its liberation on the flood involves an enormous dilution by the inflowing sea water. The outfall is about 6 miles distant from the nearest cockle beds, and the estuary here is about 6 miles in width, and it is about 4 miles distant from the nearest mussel bed. The Southport sewage is treated by septic tanks and continuous bacterial filters. The Birkdale sewage is treated by sedimentation, filtration and irrigation. Both Southport and Birkdale sewage discharge into a brook at Crossens, which continues as a gutter across the sands towards Pinfold Channel. The sewage from Lytham, Ansdell, Fairhaven and St. Anne's is discharged into the channel in the crude condition.

The shellfish beds in the Ribble estuary are situated on the lower parts of the sandbanks—Horse Bank, which is to the south of the channel, and Salter's Bank, which is mainly to the north. Mussels are not important, and the only beds at present are those at St. Anne's, on the foreshore sloping down to what used to be the North Channel; one or two small banks on the foreshore and in

the channel near Lytham; and a bed in the Ribble channel close to the training wall and nearly opposite Ansdell. The cockle beds are very numerous and important. They occur over a great part of the lower part of Horse Bank sloping down Pinfold channel, on the "Brow," that is. They also occur over a great part of Salter's Bank, mainly to the east of the New Gut Channel. These cockle beds vary greatly in their precise position from year to year. Spat falls and new beds of small cockles are formed, and are fished when the shellfish attain legal size. Also old beds become sanded up by the shifting of the banks and channels, or by heavy seas.

The pollution of the shellfish is not so great as might be expected, considering the enormous volume of sewage which enters the estuary. This is partly due to the enormous dilution which the sewage undergoes, and partly to the fact that the greater part of this—the Preston, Southport and Birkdale sewage—is treated before entering the sea. "Our general impression," say the Royal Commissioners on Sewage Disposal, "of the whole Ribble estuary was very favourable. In spite of the extensive and populous district draining into it, and the varied industries contributing their trade effluents, no marked indications are to be found, even a few miles below Preston, while at Lytham all signs have disappeared." (*Report* V., *Appdx.* VI. [cd. 4284]. 1908.) We see here, as also in the case of the mussel beds at Morecambe, the conditions that obtain when even an enormous volume of sewage enters a wide estuary, almost an open sea area, in contrast with the conditions that are exhibited when a very much smaller volume of sewage enters a narrow estuary, as in the case of Barmouth, Aberdovey and Conway, in Wales, and the Lune, in

Lancashire. The pollution of the cockles on Horse Bank must be a remote one, that is, the distance between the shellfish beds and the place of origin of the sewage is considerable; the sewage passes a certain time in tanks, filter beds, and in land under sewage irrigation, and the contained intestinal bacteria are subjected to conditions which are very different from those which they experience in their normal habitat in the human intestine. All this means that its nature becomes different from what it originally was. Therefore, although the bacteriological impurity, revealed by the preliminary analyses made in connection with this investigation, is equally gross in the case of the Ribble channel and the Aberdovey mussels, yet the pollution at Aberdovey is far more dangerous; since only a short distance separates the shellfish from the drains contributing the sewage, and only a few hours may elapse between the voiding of human *Bacillus coli* and its ingestion by the mussel.

The conditions all over the Ribble estuary are, of course, not uniform in this respect. The cockles on Horse Bank, even only a mile or so from the end of Southport Pier, may be regarded as free from significant pollution. No sewers open into the sea near the Southport shore, except some pipes conveying surface water. The effluent from Southport and Birkdale flows down Crossens Pool and Channel, and high banks separate this for a considerable distance from the cockle beds. Unless, as Dr. Bulstrode points out, cockles gathered here are washed in Crossens channel they are hardly likely to be polluted. In 1907 I made an analysis of cockles taken from a place about a mile east from Southport Pier. The mean number of sewage bacteria estimated as being present per shellfish was 12, a result which is practically the same as that obtained in the case of cockles taken

from Morecambe Bay, out from Flookburgh—a place that we can hardly imagine is polluted by sewage. These Southport cockles may, then, be regarded as pure. But the case was very different with cockles taken from the sands near Ansdell. Here the bacterial contents were about 2,000 sewage bacteria per cockle. These results, moreover, correspond with the reputation of the shellfish: no epidemiological evidence is forthcoming with regard to the Southport cockles, whereas those gathered near Ansdell and St. Anne's have been regarded with strong suspicion as carriers of disease.

This bacteriological impurity is to be associated with the direction taken by the flow of the diluted sewage. Not only does the contaminated ebb-tide water from the upper part of the Ribble channel flow near to the cockle beds between the old North Channel and the New Gut Channel, but the influence of the sewer outfalls at St. Anne's and Ansdell is apparent here. This recently-discharged sewage is far more serious than that coming down from Preston, or perhaps across from Southport. It is, indeed, unlikely that much of the sewage from the two last sources can reach the cockle beds on Salter's Bank, for the ebb-stream sets out to sea through the main channels, Pinfold, Old Gut and New Gut. On the other hand, the fairly strong flood and ebb streams set parallel to the land along the depression—that of the old North Channel—which exists close inshore from St. Anne's down to Fairhaven, and both streams must pick up the sewage from St. Anne's and Ansdell and distribute it along the edges of the banks. The contamination of these cockles may therefore be not very remote, and of course the degree of contamination in the close inshore beds may be fairly considerable.

The mussel beds are also exposed to very different

conditions. Those in the Ribble channel near the training wall are exposed to pollution by sewage coming down from Preston and Lytham. It seems hardly likely that the influence of the Preston sewage is appreciable—the distance, in space and time, between original discharge and ingestion by the shellfish is too great—but the part of the pollution which is of significance is probably that due to the Lytham sewers. But even this is about 2 miles distant from the bed sampled. The results of the analysis of these mussels were certainly bad, bacteriologically; they were practically the same as those of the Aberdovey mussels, but I should hesitate at assessing these results at their face value, for the reasons indicated above. "Both these Lytham beds," says Dr. Bulstrode, "are not, therefore, free from risks of pollution by sewage." But, on the other hand, epidemiological evidence of their rôle in transmitting disease is lacking.

The case of the St. Anne's bed is entirely different. Here we have mussels which are, some of them, "literally bathed in sewage." The bed is one of a class to which also belong those at Aberdovey and Barmouth, that is, they are in close proximity to sewer outfalls which discharge straight from town drains, without the intermediation of tanks or screening, or treatment of any kind. One has no hesitation in saying, apart from bacteriological results, that they ought to be condemned, or made the objects of some remedial treatment. "It must still be regarded as dangerous," says Dr. Bulstrode, speaking of the Aberdovey bed, "to dredge for mussels in the vicinity of an outfall"; and with regard to the Barmouth bed: "It is clear that there is great danger from the consumption of mussels dredged up from the vicinity of the estuary outfall";

and with regard to the St. Anne's bed: "Needless to say, the St. Anne's mussels should not be eaten at any period of the year, and numerous cases of enteric fever have been ascribed to these molluscs at Blackpool and elsewhere."

(5) The Roosebeck Mussel Scar.

This mussel bed was examined by both Mr. Scott and myself some years ago, and I reported on some bacteriological analyses of these mussels to the Scientific Sub-Committee at the meeting in February, 1913. A further analysis of the Roosebeck mussels, by precisely the same methods as in the cases of the Welsh estuarine areas, is, however, given here for purposes of comparison. This is an uncontaminated mussel bed, and the bacteriological results are in strict accordance with what an inspection shows. The mean number of organisms contained in 1 mussel was 6, which may be regarded as quite a negligible quantity. Thus we have the comparison: —

Roosebeck mussels: mean number of sewage bacteria per mussel = 6.

Aberdovey mussels: mean number of sewage bacteria per mussel = 20,250.

(6) Preliminary Bacteriological Analyses.

The following tables give the results of counts of colonies of "sewage bacteria" obtained in the analyses referred to above. The colonies are such as may be presumed to have had origin in domestic sewage. In all the mussel analyses a number of these colonies have been isolated and cultivated in a number of test-media with a view to their more precise identification. This work

is not yet complete, and I hope to supplement it with analyses from some other sources. It will be published later on.

Port Madoc Mussels. 11 April, 1913.

From upper part of harbour in run of sewage. No fresh water in river.	Plate 1,	No. of red colonies, 24 ;	No. of white colonies,	0
	,, 2	,, ,, 50	,, ,,	0
	,, 3	,, ,, 80	,, ,,	0
	,, 4	,, ,, 77	,, ,,	1
	,, 5	,, ,, 30	,, ,,	0

Mean No. per mussel = 2,600.

From Gareg Goch.	Plate 1,	No. of red colonies, 6 ;	No. of white colonies,	0
	,, 2	,, ,, 10	,, ,,	0
	,, 3	,, ,, 12	,, ,,	0
	,, 4	,, ,, 5	,, ,,	0
	,, 5	,, ,, 4	,, ,,	0

Mean No. per mussel = 370.

Port Madoc Mussels. 21 April, 1913.

Upper part of harbour in run of sewage. Fresh water in river.	Plate 1,	No. of red colonies, 16 ;	No. of white colonies,	30
	,, 2	,, ,, 21	,, ,,	24
	,, 3	,, ,, 17	,, ,,	14
	,, 4	,, ,, 12	,, ,,	15
	,, 5	,, ,, 10	,, ,,	61

Mean No. per mussel = 760.

From Gareg Goch.	Plate 1,	No. of red colonies, 46 ;	No. of white colonies,	0
	,, 2	,, ,, 29	,, ,,	0
	,, 3	,, ,, 44	,, ,,	4
	,, 4	,, ,, 43	,, ,,	4
	,, 5	,, ,, 37	,, ,,	0

Mean No. per mussel = 1,990.

Port Madoc Mussels. 7 May, 1913.

From rocks at Gareg Goch.	Plate 1*,	No. of red colonies, 56 ;	no white colonies on any of the plates.
	,, 2	,, ,, 50	
	,, 3	,, ,, 53	
	,, 4	,, ,, 20	
	,, 5	,, ,, 41	

Mean No. per mussel = 1,100.

* These plates contained 1/25th instead of 1/50th mussel, as in the others analysed.

Aberdovey Mussels. 21 June, 1913.

From near Penhelyg Point.
- Plate 1, No. of red colonies, 433 ; No. of white colonies, 20
- ,, 2 ,, ,, 342 ; very numerous.
- 3 other plates with colonies equally numerous but not countable owing to fusions.

Mean No. per mussel = 19,375.

From channel near Pier.
- Plate 1, No. of red colonies, 411 ; No. of white colonies, 22
- ,, 2 ,, ,, 400 ,, ,, 61
- 3 other plates with colonies equally numerous but not countable owing to fusions.

Mean No. per mussel = 20,250.

Water in Aberdovey Estuary. 21 June, 1913.

From channel at Penhelyg Point ; 1 c.c. contained, on the average, 5 sewage bacteria.

From the channel close to the Pier ; 1 c.c. contained, on the average, 1 sewage organism.

Barmouth Mussels. 19 July, 1913.

	Plate	No. of red colonies	No. of white colonies
From channel at Aberamfrach Harbour.	1	27	0
	2	18	0
	3	75	50
	4	22	20
	5	150	numerous

Mean No. per mussel = 2,920.

	Plate	No. of red colonies	No. of white colonies
From channel at Trwyn-y-Gwaith.	1	150	10
	2	150	fused.
	3	150	0
	4	100	fused.
	5	70	0

Mean No. per mussel = 6,200.

Water Samples, Barmouth Estuary. 19 July, 1913.

1. From near rocks at Aberamfrach, 1 organism per c.c.
2. From near Railway Bridge, 1 organism per c.c.
3. From half-way between Railway Bridge and Trwyn-y-Gwaith, 1 organism per c.c.
4. From near Trwyn-y-Gwaith, 3 organisms per c.c.

Preston Channel Mussels. 29 Sept., 1913.

	Plate	No. of red colonies	No. of white colonies
From near No. 2 Perch opposite Ansdell.	1	550	30
	2	310	50
	3	450	45
	4	400	60
	5	400	60

Mean No. of sewarge bacteria = 21,000.

Water Sample from same place.

Mean No. of sewage bacteria = 485 per c.c.

Roosebeck Mussels 23 Oct., 1913.

Plate 1, No. of red colonies,	0 ; No. of white colonies,	0	This is in 1/50th mussel.
,, 2 ,, ,,	0 ,, ,,	0	
,, 3 ,, ,,	0 ,, ,,	0	
,, 1 ,, ,,	1 ,, ,,	0	This is in 1/25th mussel.
,, 2 ,, ,,	0 ,, ,,	0	
,, 3 ,, ,,	0 ,, ,,	0	
,, 4 ,, ,,	0 ,, ,,	0	
,, 5 ,, ,,	0 ,, ,,	0	
,, 1 ,, ,,	2 ,, ,,	0	This is in 1/10th mussel.
,, 2 ,, ,,	1 ,, ,,	0	
,, 3 ,, ,,	0 ,, ,,	0	

In all these analyses typical colonies, isolated by the neutral-red agar medium employed, have been grown in pure subculture and examined in detail. Several interesting questions have arisen in connection with the biological characters of the organisms isolated, such as that of a possible change in the reactions of bacteria having their normal habitat in the intestine of a warm-blooded animal and then passing into the alimentary canal of a marine mollusc. Such a possible change of character is being investigated, and will form the subject of a further report, when the biology of the micro-organisms isolated in this investigation will also be discussed.

Explanation of the Plates.

Plate I. Port Madoc and neighbouring channels.

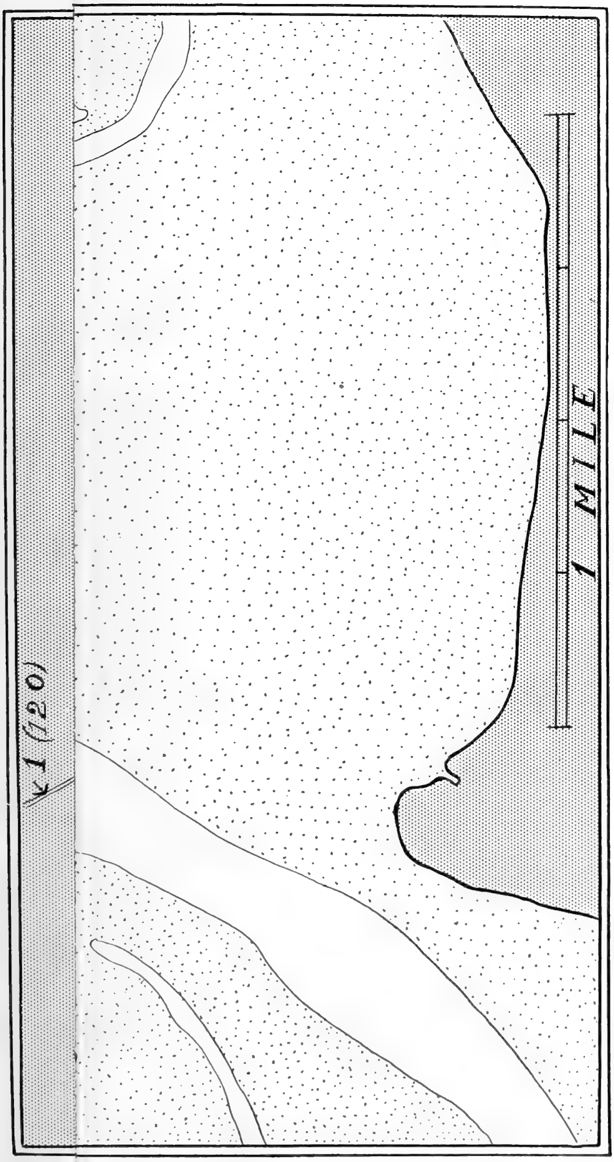
,, II. Estuary of the Dovey—Cardigan Bay.

,, III. Estuary of the Mawddach—Cardigan Bay.

,, IV. Ribble Estuary from the Sea to Preston.

,, V. 1. Organisms present in 1/50th mussel from the Ribble Estuary. 2. Organisms present in 1/50th mussel from the Dovey Estuary. 3. Organisms present in 1 c.c. of water from the Ribble Estuary.

Plate I.



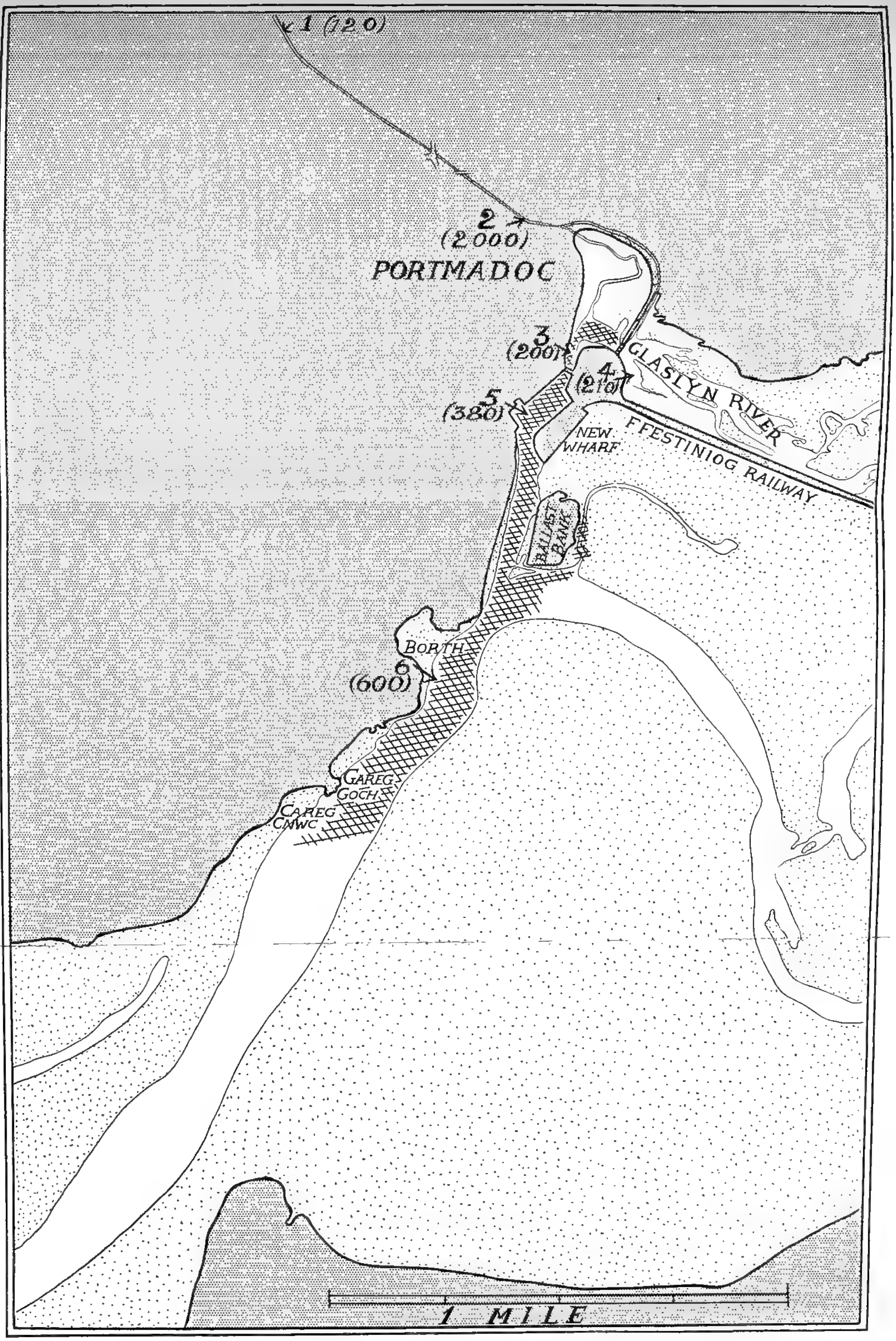
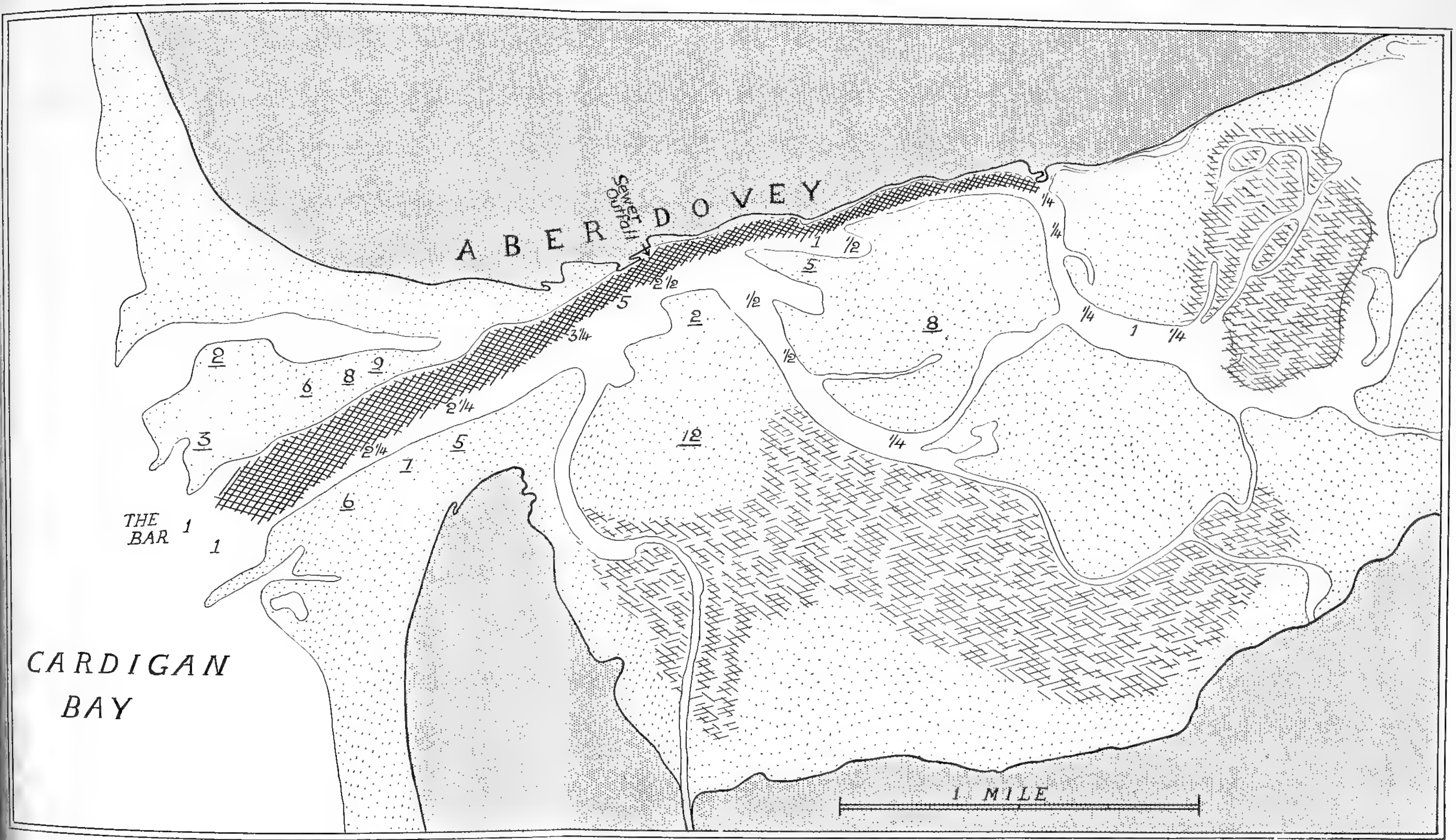
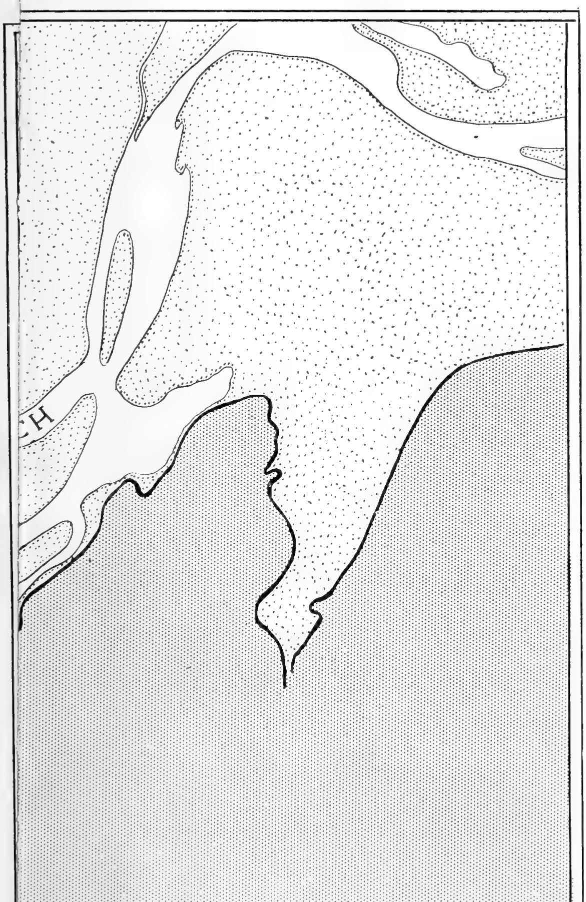
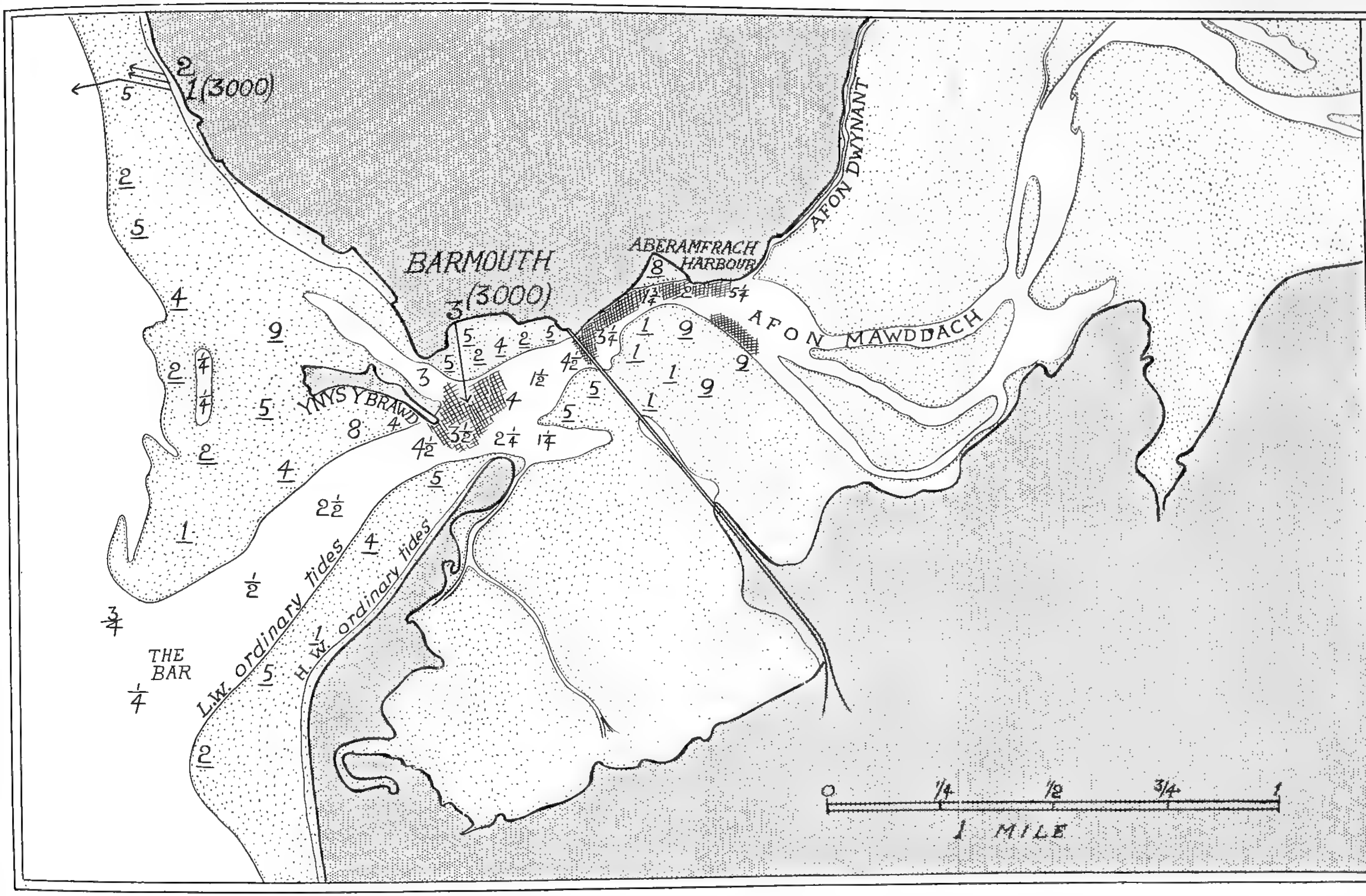

1 (120)
2 (2,000)
PORTMADOC
3 (200)
4 (210)
5 (380)
GLASLYN RIVER
NEW WHARF
FFESTINIOG RAILWAY
BALLAST BANK
BORTH
6 (600)
GAREG GOCH
CAREG CNWC
1 MILE

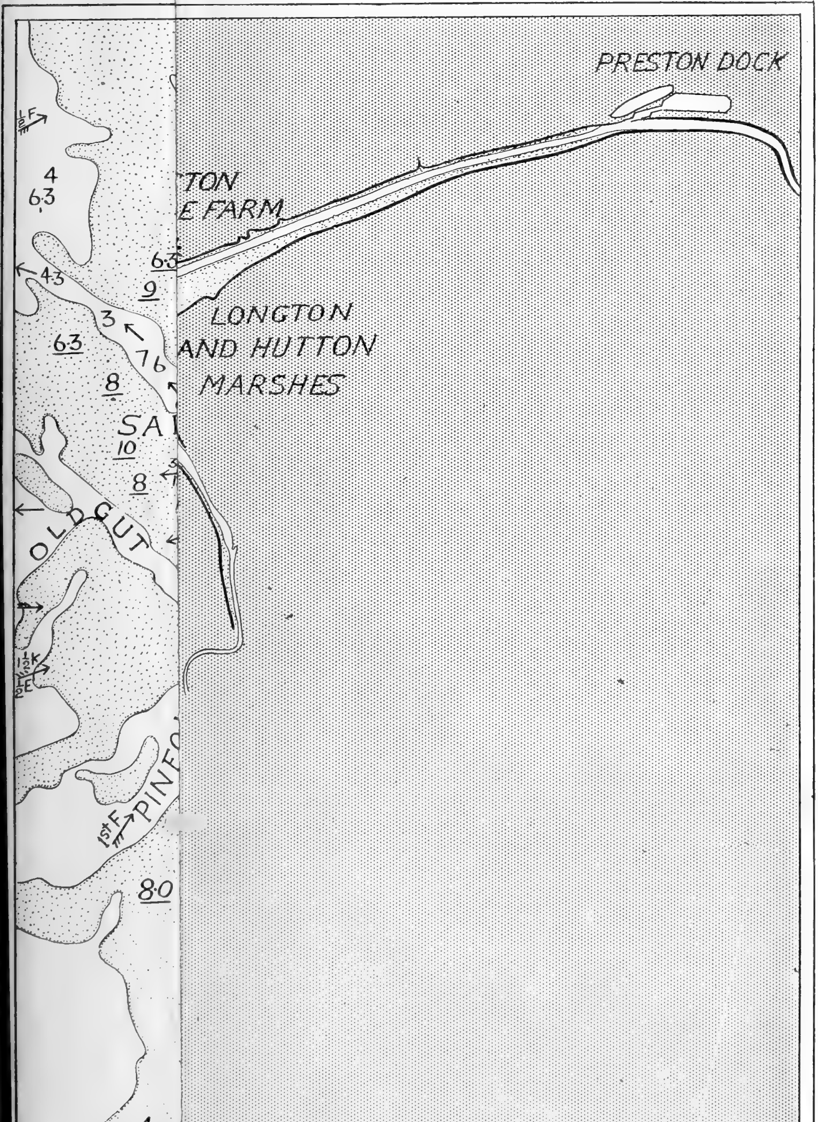
PLATE I.


1/4
1/4
1/4
1
1/4
CARD
BAY
ILE


ABERDOVEY
Sewer Outfall
CARDIGAN BAY
THE BAR
1 MILE
2
6
8
9
3
5
3¼
2½
2¼
2¼
5
7
6
1
1
2
½
1
½
5
8
½
12
¼
¼
¼
¼
1
¼
¼


CH
1/2
3/4
1
MILE


BARMOUTH
ABERAMFRACH
HARBOUR
AFON DWYNANT
AFON MAWDDACH
YNYS Y BRAWD
THE BAR
L.W. ordinary tides
H.W. ordinary tides
1(3000)
3(3000)
0
1/4
1/2
3/4
1
1 MILE


PRESTON DOCK
TON
E FARM
LONGTON
AND HUTTON
MARSHES
SA
OLD GUT
PINFO
BO

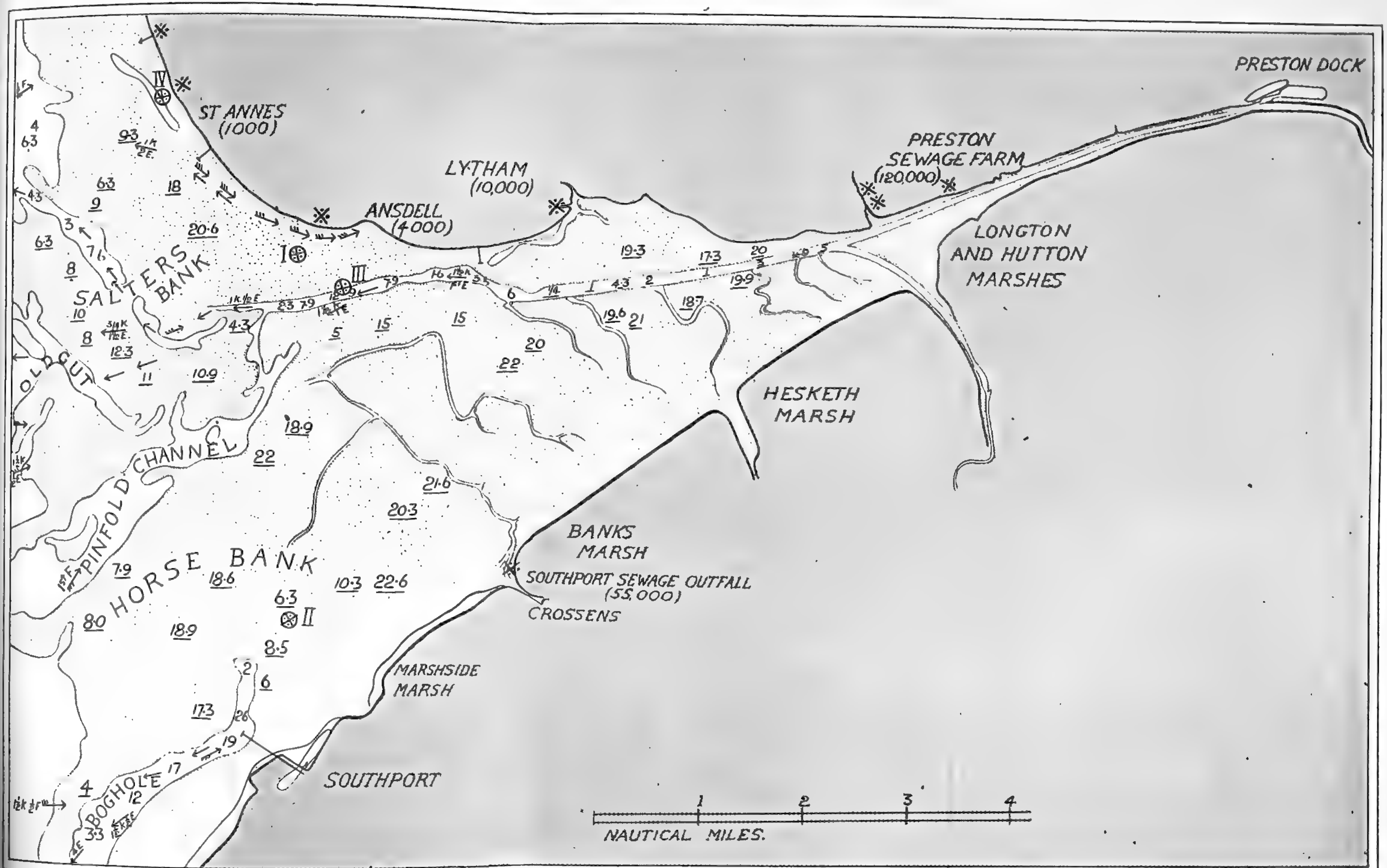
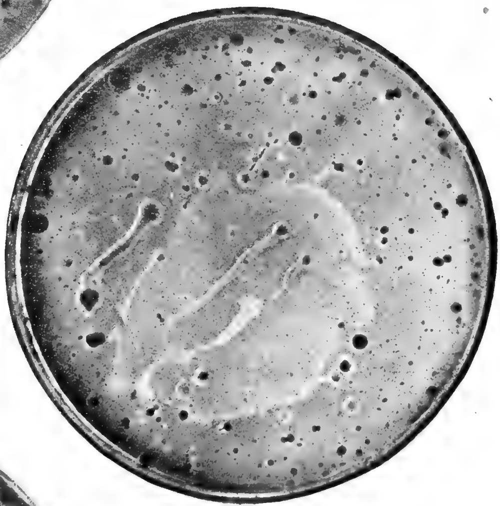
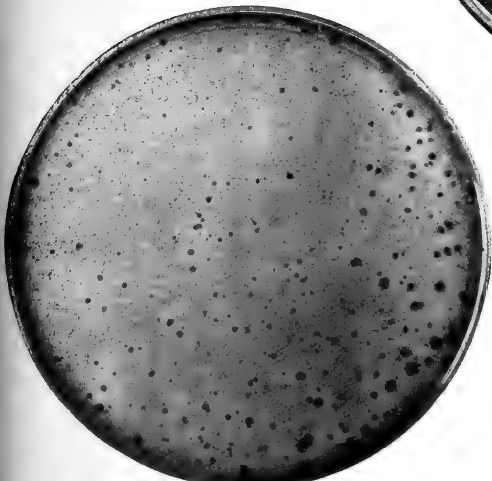

PRESTON DOCK
ST ANNES
(1000)
LYTHAM
(10,000)
ANSDELL
(4000)
PRESTON
SEWAGE FARM
(120,000)
LONGTON
AND HUTTON
MARSHES
SALTERS BANK
OLD GUT
HESKETH
MARSH
PINFOLD CHANNEL
BANKS
MARSH
SOUTHPORT SEWAGE OUTFALL
(55,000)
CROSSENS
HORSE BANK
MARSHSIDE
MARSH
SOUTHPORT
BOGHOLE
NAUTICAL MILES.
1
2
3
4

PLATE V

1. Sewage organisms present in 1/50th mussel from the Preston Channel near No. 2 Perch on the training wall.



2. Sewage organisms present in 1/50th mussel from the Dovey estuary.



3. Sewage organisms present in ice of water from the Preston Channel near No. 2 Perch on the training wall.

L.M.B.C. MEMOIRS.

No. XXII. ECHINODERM LARVAE OF PORT ERIN.

BY

HERBERT C. CHADWICK, A.L.S.,
Curator of the Biological Station, Port Erin.

The following notes and illustrative figures are the result of a careful study, extending over seven years, of the pelagic larvae of Echinodermata which occur in the plankton of Port Erin Bay. The work has been done under some disadvantage, inasmuch as I have not had sufficient leisure to enable me to study living specimens as fully as I could wish. On the other hand, I have been able to make a large collection of well-preserved specimens; and, in addition to these, I have enjoyed the unrestricted use of an excellent collection made during successive visits to Port Erin by my friend, Mr. F. H. Gravely, M.Sc., of the Royal Indian Museum, Calcutta, and formerly of the University of Manchester. I gladly take this opportunity of thanking him for so generously placing his collection at my disposal.

In addition to these two collections, I have frequently examined the official tow-nettings which have been taken twice weekly by the Staff of the Port Erin Biological Station throughout the whole period of my study of the Echinoderm larvae.

Methods.

All the larvae were captured by means of tow-nets, and the great majority of those collected by me were fixed and preserved in the boat immediately after capture; the fixative in nearly all cases being a saturated solution of corrosive sublimate, in which, however, the specimens were not allowed to remain longer than one minute. My usual practice is to invert the tow-net into a wide-mouthed bottle containing the fixative. The entire catch is then poured through an ordinary lamp chimney, over the smaller end of which a small piece of bolting silk is tightly stretched and held in position by means of a strong rubber band. When all the fixative has been strained off, the piece of silk is dropped into another wide-mouthed bottle containing 70 % spirit, and well shaken until all the organisms are free. The spirit is changed at least once on arrival in the laboratory. Gravely isolated many of his larvae, and narcotised them, especially the echinoplutei, with a 1 % solution of chloretone, and the results, especially in the later stages of the metamorphosis, are excellent. These results should, however, always be checked by fixing the contents of at least one haul of the tow-net on every occasion, as maceration of the delicate tissues of the larvae begins with capture, and is liable to mislead the student.

Historical.

The first records we have of the occurrence of Echinoderm larvae in the neighbourhood of Port Erin are those of Herdman (7), who, however, merely referred the larvae observed in the local plankton during the months of July and August, 1885, to their respective orders. More recently Herdman and Scott (8) have

recorded the occurrence of Echinoderm larvae in the plankton around the south end of the Isle of Man, and their relative number on one occasion is stated; but no attempt is made to name them nor to refer them to their respective orders, as the object of their investigation was to determine the statistics of groups rather than to identify the species. I venture, therefore, to hope that the present contribution to an exact knowledge of these interesting larvae as they occur in the above-named area may be found useful by future workers in the same field.

It may be of interest, to give some idea of the number of Echinoderm larvae which may occur at times, to quote the following sentences from the Twenty-second Annual Report of the Lancashire Sea-Fisheries Laboratory (8), p. 292:—"Echinoderm larvae were unusually abundant in 1913. Absent in January, they appeared suddenly in our nets on February 6th, to the number of 3,040, and attained their maximum of 51,200 as early as February 13th. Other large hauls were 24,080 (February 20th), 17,000 (February 27th), 24,360 (March 10th), and 27,150 (March 13th). The numbers dropped to zero by the middle of April, but Echinoderm larvae were present occasionally from this time on to the end of October, and on July 17th there was a large haul of 30,000. Twice in September the numbers reached the thousands (7,400 on the 11th, and 4,000 on the 18th)." These figures represent the number present in the official hauls across Port Erin Bay. The large numbers stated as having occurred in February and March refer to the as yet unidentified spatangoid pluteus shown in figs. 61-64, Pl. IX, and the ophiopluteus shown in fig. 37, Pl. VI. The former was much the more numerous. A few bipinnariae of *Asterias rubens* may be included; but, compared with the spatangoid pluteus, the number was insignificant.

Thirty-five species of Echinodermata have been recorded from the conventional area of the Irish Sea known as the L.M.B.C. District, and all are found in the immediate neighbourhood of the Isle of Man. The larvae of three species, viz., *Henricia sanguinolenta, Asterina gibbosa* and *Amphiura elegans* are non-pelagic, while that of a fourth, *Antedon bifida,* is pelagic for only a brief period. In the present paper only the pelagic forms come under notice; and of these, twelve can with certainty be referred to their respective species.

The occurrence of Echinoderm larvae in nearly all the months of the year has been observed; but, so far as my own experience goes, the largest number of individuals appear in the latter half of February, July, early August, and the greater part of September. These records refer particularly to the years 1907 and 1908, when a large proportion of the specimens upon which this memoir is based were collected. Most of the same species were observed in the years 1909 and 1910, but in remarkably diminished numbers. The records of Scott (14) show that in the year 1906 Echinoderm larvae were present in the plankton of Port Erin Bay in March and September, but these records are probably incomplete. In September, 1911, 1912, and 1913, several species observed in July in previous years appeared in diminished numbers. In March and April, 1914, one spatangoid pluteus was abundant, while one ophiopluteus and two Asterid larvae were not uncommon at the end of March and in April.

Larvae of Asteroidea.

Considering the fact that twelve species of Asteroidea are found in the immediate neighbourhood of Port Erin, and that the larvae of at least eight of them are known

to be pelagic, the small number of species of these larvae, four or five at most, which have come under my notice is somewhat disappointing. On the other hand, no Echinoderm larva with which I am acquainted has appeared in such large numbers as that of *Asterias rubens* (Pl. I, figs. 1-9), which I have been able to identify satisfactorily by comparing those taken in the plankton with others reared from eggs fertilised naturally in one of the tanks of the Port Erin Aquarium. On several occasions I have seen a few examples of the blastula (fig. 1) and early gastrula (fig. 2) stages as early in the year as the end of January; but during the years 1907 to 1912 inclusive, the species appeared in great force about the middle of February, when every stage, from the gastrulating blastula to the early bipinnaria (figs. 2-9) was obtainable in the plankton, and furnished abundant material for a study of the earlier stages of development. In February, 1913, careful search through a number of tow-nettings failed to reveal a single specimen of this larva, but it re-appeared at the same time in 1914. I have met with the stages represented in figs. 8 and 9 in large numbers in the early part of March; but later than this they have disappeared from view; and I have not been able to trace the later bipinnaria and brachiolaria stages. The course of development of the early stages is in complete accord with that of the larva of *Asterias vulgaris* as described by Field (1). Fig. 4 represents, from the ventral surface, an early bipinnaria stage, in which the coelomic vesicles are seen budding to right and left from the blind end of the archenteron. The latter is bending ventrally, as shown in the slightly diagrammatic optical section (fig. 5), to meet the stomodaeal invagination (*std.*). The blastopore (*bl.*) is moving forward towards the ventral surface of the larva.

Fig. 7 represents from the left side a slightly later stage in which the stomodaeal invagination has met and opened into the hitherto blind end of the archenteron. The three divisions of the gut—oesophagus (*oes.*), stomach (*st.*), and intestine (*int.*) are now well defined. Communication between the left coelomic vesicle and the exterior is established by a tubular outgrowth—the pore-canal (*p.c.*) —from the vesicle, which meets and fuses with an invagination from the dorsal wall of the larva. The invagination becomes perforate, and forms the madreporic pore (*m.p.*). The same organs are seen in fig. 6, which is a ventral view of a slightly older larva. Here the pre-oral and post-oral portions of the ciliated band (*c.b.*) also are clearly defined. In fig. 8, a still later stage, the whole of the ciliated band is defined, and the pre-oral lobe (*pr.o.l.*) has assumed its characteristic shape. The stomach is now large and subglobular. Both coelomic vesicles, the left (*l.c.*) much the larger, are beginning to grow forward in the direction of the pre-oral lobe. In fig. 9, the latest stage of this larva which I have been able to trace with certainty, this forward growth has proceeded much further, and the posterior portions of the vesicles have begun to envelop the stomach. The walls of the vesicles are now much thinner, and, except in the living larva, are traced with difficulty. Field (1) discusses at some length the occurrence of a right hydrocoel in some of the larvae of *Asterias vulgaris* studied by him. Gemmill (4) has recently shown that this interesting feature occasionally occurs in the larvae of *Asterias rubens* and *A. glacialis*, and (5) in that of *Porania pulvillus*. I have not observed it in the larva just noticed.

In a recently published paper "on the Development of some British Echinoderms," Mortensen (13),

figures the four-weeks-old bipinnaria stage of the larva of *Asterias glacialis*, which he had reared from artificially fertilised eggs in the Plymouth Laboratory. This figure enables me to identify the bipinnaria represented in fig. 10, Pl. I, which was captured in a tow-netting in Port Erin Bay in April, 1911, and is, I doubt not, the larva of *Asterias glacialis*. A number of specimens of this larva were found in every haul of the tow-net taken at the end of March, and it was still fairly common at at the time of going to press (April 20th, 1914). Its occurrence in previous years was rare. The only essential difference between the specimen figured by Mortensen and that from Port Erin lies in the disposition of the ciliated band, which may be accounted for by assuming a slight difference in age. In both larvae the right and left coelomic vesicles had grown forward and united in the pre-oral lobe. Mortensen does not figure any communication of the left vesicle with the exterior through a pore-canal and water-pore, and I also was unable to find any trace of these structures in the Port Erin specimen.

I am again indebted to Mortensen's paper for help in identifying the larva represented from the left side in fig. 11, and from the ventral face in fig. 12, Pl. II. It occurred in very small numbers in the plankton in June and July, from 1905 to 1909 inclusive, but like some other Echinoderm larvae has not come under observation during the past four years. It is the larva of *Luidia ciliaris*. Mortensen reared this larva also from artificially fertilised eggs. The specimens from which my figures were drawn were older than the five-weeks-old one figured by Mortensen, inasmuch as in the former the arm-like processes characteristic of the brachiolaria have attained some length, while in the latter they have scarcely begun

to develop. *Luidia ciliaris* is not a common species in the neighbourhood of Port Erin; and, so far as my knowledge of its distribution goes, is confined to the deeper waters. So far as the experience of Gravely and myself goes, the occurrence in the plankton of Port Erin Bay of brachiolariae undergoing metamorphosis is rare. Gravely's collection contains three, evidently of one species, taken in August (fig. 13, Pl. II), and my own collection but one, taken in June. Mortensen informs me that on certain parts of the coast of Denmark metamorphosing brachiolariae of *Asterias rubens* may be seen swimming at, or near, the surface of the sea in large numbers during July; and one of the American species is represented by similar numbers in the waters of Wood's Hole. Their rarity in Port Erin Bay and its neighbourhood cannot, therefore, be explained by the assumption that when passing through their later stages these larvae seek the deeper waters.

Figs. 14 to 18, Pl. II, represent stages in the development of the larva of *Solaster*, but whether of *S. papposus* or of *S. endeca* I cannot say with certainty at present. Both species occur in the immediate neighbourhood of Port Erin, but *S. papposus* is probably the more abundant. Comparison of my figures with those of Gemmill (3) will show that there is close agreement, at least in external form, between the larvae from the plankton of Port Erin and those of *S. endeca* reared in the Biological Station at Millport. It is probable, however, that both species are represented. The larva shown in fig. 19 is very similar to that of which the external form only is shown in fig. 18, Plate II, of Gemmill's paper. It is probably not of the same species as that shown in figs. 15 to 18, but the few details of its structure which I have drawn show that the two are closely related. My

first acquaintance with this interesting larva was made so long ago as May, 1892, when, in a tow-netting, I took a specimen which had reached the stage of development represented in fig. 17. At that time I felt confident that the five-rayed structure which came into view when the specimen had been mounted in balsam was a hydrocoel, and that the organism would prove to be the larva of an Asterid. I was led to refer it to *Solaster* by seeing an adult specimen of *S. papposus* extrude a number of comparatively large, orange-coloured eggs in the Aquarium of the Port Erin Biological Station. Its identity has now been established beyond doubt by Gemmill. The larva of *Solaster* occurs in the plankton of Port Erin Bay in small numbers in April and May. Its bright orange colour, contrasted with the dull green of the vernal phytoplankton with which it is usually associated, makes it a conspicuous object in plankton gatherings. In the paper cited above, Gemmill states that many of the larvae of *Solaster endeca* which he collected by means of the townet in the neighbourhood of Millport, "showed minor abnormalities of growth," and from this circumstance he infers that it is "chiefly unhealthy larvae which come to the surface of the sea. They are soft and readily break up against the cloth of a tow-net." My own experience accords with this; but I have obtained from plankton gatherings in successive years a number of these larvae in various progressive stages, from the segmenting egg to that in which metamorphosis is nearly complete (fig. 18). It is noteworthy that even at this late stage of development, of which I have seen only one example, the larva is still five-rayed. Gemmill gives an account of the mode in which it attains the many-rayed condition of the adult. Owing to the opacity of the orange pigment, it is not possible to make out the position and

relations of the coelomic and other internal structures in the living larva. All the specimens from which figs. 14 to 19 were drawn were lightly stained in borax carmine, and mounted without pressure in balsam.

Larvae of Ophiuroidea.

Seven species of Ophiuroidea have been found in the neighbourhood of Port Erin, and Gravely and I have distinguished eight ophioplutei, which occur more or less abundantly in the plankton of the bay. The larva of one species, *Amphiura elegans*, is, however, not pelagic; so that it is probable that two of the ophioplutei represent species which either have not yet been discovered in the district or occur in the deeper waters outside its limits.

The species to which I would first draw attention is one to which Mortensen (12) has given the temporary name "mancus." It occurred in considerable numbers, along with the species to be next described, in July, 1907, and 1908, respectively, and is easily recognised; the postero-lateral arms being gracefully curved, and the skeletal rods which support them bearing slightly curved spine-like projections at tolerably regular intervals along their inner sides, as shown in fig. 20, Pl. III. The tips of these arms, as well as the posterior end of the body, are tinged with orange or red pigment. Gravely and I found this species a favourable one for the study of the main features of the development of the coelomic vesicles, especially the hydrocoel, and of the primary elements of the skeleton of the adult. It is practically free from the dark pigment which so much obscures structural detail in the pluteus of *Ophiothrix fragilis*. Fig. 22 is a ventral view of a young pluteus in which the right and left coelomic vesicles have just divided into

anterior (*r.a.c.* and *l.a.c.*) and posterior (*r.p.c.* and *l.p.c.*) portions, and are taking up their characteristic positions, the two anterior ones alongside the oesophagus and the two posterior alongside the stomach, as shown in fig. 21, which also is a ventral view of a young pluteus.

In fig. 23, the first indication of the formation of the five-lobed hydrocoel (*hy.*) is seen. This organ, according to MacBride (11), is budded off from the left anterior coelom, but is not completely separated from it. The anterior portion of the original vesicle, as well as the tubular portion—the future stone-canal—connecting it with the hydrocoel, is but rarely discernible in whole preparations, and is not represented in the figures. The hydrocoel now enlarges considerably, and extends along the entire length of the oesophagus (fig. 24), while the right anterior and the two posterior vesicles remain practically of the same size, and, up to this point, have undergone no further development. The metamorphosis of the larva into the post-larval Ophiurid is now initiated; and the hydrocoel, apparently losing, for the time being, its five-lobed form, proceeds to surround the larval oesophagus (figs. 25 and 28, Pl. IV). The further details of the metamorphosis cannot be satisfactorily studied without recourse to serial sections. A short account of the development of the primary elements of the skeleton of the adult, as illustrated by a considerable number of metamorphosing larvae, may, however, be here given.

In fig. 26, Pl. IV, which shows a larva viewed from the ventral surface, there appear on the right side (left of the figure) five minute, tri-radiate calcareous plates (*rl.*), three of which lie upon the dorsal surface, and two upon the ventral surface of the larva. These eventually become the radial plates of the disc of the adult Ophiurid. On the left side (right of the figure) other five plates (*tl.*)

appear, and represent the terminal plates which, at an early period, take up, and maintain throughout life, their respective positions at the tips of the five arms. Fig. 27 represents a slightly more advanced stage. Here the radial plates have enlarged considerably; and a sixth plate, the central (*cn.*), has appeared in their midst. The five terminals have scarcely altered their respective positions; and at a little distance anterior to them another very minute tri-radiate plate (*ad.*) has appeared, and is probably the madreporic plate. Further than growth of the several plates, little change is represented in fig. 28, though three of the terminals have become slightly more complex. In fig. 29, however, the future Ophiurid is seen to be taking shape. The central and the five radials have increased considerably in size and still lie to the right of the larva. The terminals are seen to be taking up their respective positions; and a few very minute plates, probably adambulacrals, have appeared. In the specimen from which fig. 30 was drawn the plates of the apical system—central and radials—have taken up their permanent positions, with the terminals in exact correlation with the radials. In fig. 31, Pl. IV, the aboral skeletal plates of the still pelagic post-larva are represented. In the living post-larva of this age a pair of tube-feet in each ray may be seen in active movement, and are functional as organs of locomotion.

Abundant in July, 1907 and 1908, "ophiopluteus mancus" was represented only sparingly in 1909, since when its occurrence has been rare. Graham Kerr (6) records the common occurrence of this species in September in Loch Sween. He distinguishes it by the letter C, and appears to have some doubt as to its identity with Mortensen's ophiopluteus mancus. There is, however, no doubt that his,

Mortensen's, and my own figures represent the same organism. Speculation as to the adult form of this larva is of little value; but I would like to record my impression that it will eventually be found to be *Ophiopholis aculeata*.

The larva of *Ophiothrix fragilis*, figs. 32 to 36, Pl. V, is easily recognised by its exceptionally long, straight postero-lateral arms, which are banded at intervals with black pigment, and persist until the metamorphosis of the larva is complete. Owing to the comparative thickness and consequent opacity of its body, and to the quantity of pigment developed in the tissues, the later stages of the development of this larva, and the appearance of the primary elements of the skeleton of the adult, were much less easily observed than those of ophiopluteus mancus. In fig. 33, which is a ventral view of a young pluteus of this species, the anterior and posterior coelomic vesicles have taken up their respective positions, and the left anterior one is about to divide into anterior and posterior portions. In fig. 34, also a ventral view, this has taken place, and the posterior portion of the left anterior vesicle is the hydrocoel. On the right, the posterior vesicle, though defined, is still continuous with the anterior one. In fig. 35, which should be compared with fig. 29, Pl. IV, a stage is represented in which all the primary plates of the skeleton are present and occupy their respective relative positions in the now clearly defined disc of the post-larva. The latter, freed from all traces of the pluteus, and having five distinct arms provided with sub-terminal claws (fig. 36), was abundant in the plankton in late July and early August in the years 1907 and 1908. In the same months of 1909 this larva was only sparingly represented. It was not observed by me in July in the three succeeding years, but re-appeared in

comparatively small numbers in that month of 1913. In 1911, it appeared in small numbers at the latter end of September; was more abundant at the same time in 1912; and at the corresponding period of 1913 was more abundant than in the earlier years. Graham Kerr (6) records its occurrence "in immense swarms" in the waters of Loch Sween in September.

Fig. 37, Pl. VI, represents an ophiopluteus which Mortensen (12) doubtfully correlates with *Ophiopholis aculeata*, an Ophiuroid which, owing to its habit of concealing itself in the cavities of stones, especially those bored by *Saxicava*, is probably much more abundant in the neighbourhood of Port Erin than is generally supposed. A rather large and conspicuous form, this larva came under my notice for the first time in February, 1912, when a few examples of the younger stages appeared in the plankton for a short time only. It again appeared in February, 1913, and occurred in fair numbers in most of the plankton gatherings until the end of March, when it disappeared without affording me opportunities of observing the metamorphosis.

I have now to describe briefly an ophiopluteus which was first detected in the plankton of Port Erin by Gravely, and named by him the "epauletted" pluteus (fig. 38, Pl. VI). This provisional name refers to the four epaulettes formed by the ciliated band at the base of the postero-lateral arms, a feature so conspicuous as to make the larva easily recognisable. The ends of all the arms are somewhat club-shaped. Noticed for the first time in July, 1907, and again recorded in the same month in 1908, its occurrence in our local plankton was comparatively rare; and I have not observed it since 1909. Graham Kerr (6), on the other hand, records its occurrence in "immense

numbers" in the waters of Loch Sween, in the early part of August, 1911. Also, he precedes Gravely and myself in recognising its resemblance to Mortensen's ophiopluteus henseni, as figured in his "Echinoderm Larvae of the Plankton Expedition," and we agree with him in regarding the two as distinct.

The ophiopluteus represented in figs. 39 to 42, Pl. VI, is almost certainly the pluteus paradoxus of Müller, which is correlated by Mortensen (12) with *Ophioglypha albida* (Forbes), now more correctly known as *Ophiura albida*. It is easily distinguished by its broad arms, the postero-lateral ones rather strongly curved, and by the cap of ciliated cells—possibly a sense organ—which covers the posterior end of the body, and is always rendered conspicuous by staining. The only particular in which this Port Erin form differs from that figured by Mortensen is the absence of the sharp, well-developed spines which are represented as projecting at right angles from the skeletal rods of the arms. Graham Kerr (6) found an ophiopluteus in Loch Sween which he considers identical with that figured by Mortensen; but in his figure as in mine the skeletal rods are represented as spineless. Fig. 40 represents an early stage in the metamorphosis of this larva. The hydrocoel has almost completely surrounded the oesophagus. On the left side of the body and overlying the large, oval stomach, are five rounded elevations, each supported by a crescentic terminal plate (*tl.*). These are the rudiments of the five arms of the adult Ophiuroid; three being situated dorsally and two—indicated by terminals figured in black—ventrally. On the right side the central (*cn.*) and the five radials (*rl.*) are seen. On the left side, anterior to the terminals and overlying the hydrocoel, is a small adambulacral plate (*ad.*), and on the extreme right is the

minute madreporic plate (*m.pl.*). The post-larva, still associated with the remains of the pluteus (fig. 41), and after complete separation therefrom (fig. 42), occurred frequently in the plankton. In the former figure, taken from the oral face of the post-larva, only a few of the skeletal plates, including the oral halves of the basket-like terminals, are represented; in the latter, taken from the aboral face, the central, the five radials, and the aboral faces of the five terminals are shown. A remarkable circumstance in connection with this larva is the frequency with which the gut and the coelomic vesicles become aborted and disappear. With regard to the time of its occurrence it may be stated that it has always appeared along with that of *Ophiothrix fragilis* and with ophiopluteus mancus. It occurred in considerable numbers in July, in the years 1907 and 1908 respectively, but was very rarely seen in 1909 and 1910. It reappeared in small numbers in September, 1911, was more abundant in the same month of 1912, and was abundant in July and September, 1913. In all the specimens of this pluteus examined in the last-named month, all the skeletal rods were traversed by a central canal, as shown in fig. 39A. I have seen traces of this in other plutei.

Mortensen (12) correlates with *Ophioglypha texturata* (Lamk.) = *Ophiura ciliaris* (Linn.) the larva shown in fig. 43, Pl. VII. It may be at once recognised by the linear series of perforations and blunt spines which ornament the skeletal rods of the postero-lateral arms. Compared with the size of the body of the pluteus all the arms are rather short and stout, and their skeletal rods bear blunt spines. This is one of the less common ophioplutei; and I have hitherto seen only one specimen in which metamorphosis had begun. It occurred sparingly in Port Erin Bay in July and early August,

in 1907 and 1908, and reappeared in rather larger numbers in September, 1911 and 1912. It was rare in July and September, 1913. Graham Kerr (6) records it from Loch Sween, and says it was the least numerous of the five ophioplutei found therein. Should Mortensen's correlation of this larva with *Ophiura ciliaris* be correct, it shows that the plutei of two closely allied species such as *Ophiura ciliaris* and *O. albida* may be dissimilar (compare figs. 39, Pl. VI, and 43, Pl. VII). Though by no means uncommon in the deeper waters around the South end of the Isle of Man, *O. ciliaris* occurs much less frequently in dredgings than its relative *O. albida.*

Figs. 44 and 45, Pl. VII, represent an ophiopluteus of which only two specimens have hitherto been observed in the plankton of Port Erin. The first, from which the figures were drawn, was found by Gravely in a tow-netting taken on July 22nd, 1909. In spite of careful search through a considerable quantity of plankton taken during the same month in each succeeding year, no other specimen was seen until about the same date in July, 1913, when, during a short visit to the Port Erin Biological Station, Dr. Mortensen was so fortunate as to find a second specimen. After careful examination of this larva in the living state, Gravely identified it with the ophiopluteus compressus of Mortensen (12), and with this I agree. All the arms are long and slender, the postero-lateral ones (*pto.l.a.*), banded at intervals with black pigment and very slightly incurved at their tips, especially so. The three remaining pairs of arms are of sub-equal length and nearly straight. The skeletal rods of the postero-lateral arms are furnished with minute spines. The transverse and end rods of the skeleton are reminiscent of those of ophiopluteus paradoxus; and the similarity between the two forms is further emphasised

by the cap of deeply-staining cells at the posterior apex of the body. A full-grown larva, the specimen captured by Mortensen had not entered upon its metamorphosis. In Gravely's specimen all the primary elements of the skeleton of the adult are present (fig. 45). Figure 44, drawn under a low power, shows the five terminal plates (*tl.*), three dorsal and two ventral, which have already assumed the characteristic basket-like form of these plates, and project as slight eminences from the general surface of the body. Figure 45, drawn under a higher power, shows the three of these plates which lie upon the dorsal face of the body and are visible in one and the same focal plane. The madreporic plate (*m.pl.*) overlies the hydrocoel (*hy.*), which has moved some distance forward along the oesophagus preparatory to encircling that organ. On the right side of the body the central (*cn.*) and three of the radial plates (*rl.*) are shown.

There remains to be mentioned only one Ophiuroid larva; and, owing to the fact that I have seen only two or three of the latest stages of the metamorphosis and no growing plutei, I cannot describe it in detail. Figure 46, Pl. VII, was drawn from one of several specimens found in the plankton in December, in which month alone this larva has hitherto occurred in successive years. It was carefully searched for, but not seen in 1913. In this the central, radial and terminal plates have taken up their respective positions in the disc of the future Ophiuroid. Of the pluteus only the postero-lateral arms remain; but the form of the proximal ends of the skeletal rods of these and of the posterior and transverse rods is sufficient to indicate the specific distinctness of this larva from those described above. On one occasion I had the good fortune to see the post-larva (fig. 47) free itself from the remains of the pluteus and move about actively by means of its

tube-feet (*t.f.*). Figure 48 represents a young and still pelagic Ophiuroid, probably of the same species as the ophiopluteus shown in fig. 37, Pl. VI, found in the plankton on April 19th, 1909.

Larvae of Echinoidea.

Seven species of Echinoidea are known to occur in the L.M.B.C. District; and of these the larvae of five, viz., *Echinus esculentus*, *E. miliaris*, *Echinocyamus pusillus*, *Spatangus purpureus* and *Echinocardium cordatum*, are known with certainty, having been reared from the egg by MacBride (10), Théel (15), Krohn (9), and others. Gravely and I have recognised the first three, and the fifth, in the plankton of Port Erin. Of the remaining three larval forms one is well known to me, but not yet satisfactorily correlated with its parent species.

Probably no member of the marine fauna of Port Erin is more familiar, alike to the student of Zoology and to the casual visitor, than the common sea-urchin, *Echinus esculentus*. The ruined breakwater, the boulder-strewn beach at low tide, and the depths beyond low-water mark in which the dredge is used, all furnish an abundant supply of specimens. In view of this fact the rarity of the occurrence of its larva (figs. 49 and 50, Pl. VIII) in plankton gatherings is remarkable. My first acquaintance with this larva was made so long ago as June 23rd, 1900, when I found a few fully developed plutei in a tow-netting remarkable for the variety and interest of the larval forms it contained. Since that time I have again and again made careful search for it, by using the tow-net at the surface, in mid-water, and sunk by means of a weight to within a few feet of the bottom, but with only a very small measure of success. The breeding season of *Echinus esculentus* occurs in the early spring. In the

middle of March, 1913, I had no difficulty in obtaining and fertilising an abundant supply of eggs; and, during recent years, many workers at the Biological Station have had the same success throughout April. It may be mentioned in passing that ripe adults may generally be stimulated to emit the genital products from the gonads by exposing the tank in which they are kept to direct sunlight, or by adding some slightly warmed sea-water. The fully developed echinopluteus stage of the larva of *Echinus esculentus* may be at once recognised by its possession of two series of ciliated epaulettes (fig. 49, Pl. VIII, *a.c.ep.* and *p.c.ep.*) which are charged with reddish-yellow pigment. Even at an earlier stage, when the anterior epaulettes only have developed (fig. 50), it may be distinguished from the larva of *Echinus miliaris* by its larger size, more rounded form and comparatively longer arms.

Echinus (or *Psammechinus*) *miliaris* is a much less abundant species in the neighbourhood of Port Erin than *Echinus esculentus*. Its larva (fig. 51, Pl. VIII), on the contrary, has occurred much more frequently in the plankton, and was tolerably common in July, 1907, and again in 1908. During the same month in the three succeeding years, 1909-1911, I did not see a single specimen; but it reappeared in the plankton, along with the ophioplutei with which it was associated in the earlier years, in September, 1911, and again occurred in the same month in 1912 and 1913. The echinopluteus of *Echinus miliaris* is smaller than that of *E. esculentus*, and its antero-posterior diameter is proportionately shorter. The full-grown echinopluteus is, however, most easily recognised by having only one series of ciliated epaulettes, at the base of each of which is a rounded mass of green pigment (fig. 51, *gr.p.*). Gravely and I collected a large series of this larva, in which we were able to follow the

progressive stages of the development of the "Echinus rudiment" as it is called by MacBride (10), within the echinopluteus. In figs. 51, 52, and 53, this rudiment is seen as a dark, discoid mass closely applied to the left side of the large, sub-globular stomach. At the stage shown in fig. 53, the arms of the echinopluteus are already shortening; and on the right side of the body a single sessile pedicellaria (*pd.*) has appeared. In the next stage figured (fig. 55), the number of pedicellariae has increased to three; and in addition to numerous spicular plates (*sk.p.*)—rudiments of the plates of the test of the adult—developed on the oral face of the echinus rudiment, a number of minute spines (*sp.*) project from its surface. In fig. 54, a stage is shown in which the echinus rudiment has assumed the definite, subpentangular form of the adult. The peristomial aperture of the future test is clearly visible; and the five primary tube-feet (*u.t.*) are present, each with a rudimentary rosette in its terminal sucker. No more interesting stage was observed than that shown in fig. 56. In this a pair of tube-feet (*t.f.*) is present in each radius in addition to the unpaired one (*u.t.*) just indicated in fig. 54. In this respect the metamorphosed larva of *E. miliaris* differs from that of *E. esculentus,* in which only the unpaired one is present. At this stage two distinct kinds of spines are easily recognised. Some are similar to those of the adult, inasmuch as they taper gradually from base to bluntly pointed end. These are confined to the oral face of the young Echinus. Others are of almost uniform thickness throughout their length, and the free end is produced into three or four minute points. These are borne upon the convex aboral face. The adult mouth (*ad.m.*) is just discernible at this stage, but does not appear to be perforate. Fig. 57, Pl. IX, shows an aboral view of a post-larval but still

pelagic specimen of this species which was obtained by means of a weighted tow-net from near the bottom of Port Erin Bay. The rudiments of four of the plates of the apical system of the adult test are seen bearing the many-pointed spines and sessile pedicellariae. The two larger plates have formed around the proximal ends of two of the skeletal rods which supported the arms of the pluteus. MacBride (10) says that this strongly convex aboral surface of the just metamorphosed Echinus becomes the periproct of the adult.

Fig. 58, Pl. IX, agrees so exactly in essential details with Mortensen's (12) figure of the echinopluteus of *Echinocardium cordatum* that I have little hesitation in referring to that species a larva which occurred in considerable numbers in the plankton in July and August, 1907, and in smaller numbers in the same months of 1908.* In spite of careful scrutiny of the official tow-nettings, taken twice weekly throughout the year, it was not until September, 1913, that I noted its reappearance in very small numbers. In 1907 and 1908, the stages of metamorphosis, during the progress of which a large quantity of deep purple pigment was developed in the body of the larva, were abundantly represented; and by using a weighted tow-net a number of post-larvae were obtained from near the sandy bottom of the bay, one of which is shown in fig. 59. At this stage the five primary tube-feet are functional, and by their means the tiny animals were observed to creep slowly over the bottom of the vessel in which they were kept under observation. But perhaps the most interesting feature of this post-larva is the presence of five sphaeridia, each one closely

* MacBride has recently published in the Quart. Journ. Micr. Science, Vol. 59, Part 4, Feb., 1914, an account of the external features of the development of *Echinocardium cordatum*.

associated in position with one of the primary tube-feet, not lodged in any depression or cavity of the test, but projecting freely from its surface (fig. 60).

Spatangus purpureus occurs not uncommonly in the deeper waters in the neighbourhood of Port Erin, but I have not recognised its larva. Mortensen (13) obtained at Plymouth ripe eggs in the latter half of June, and was able to rear a number of larvae until they were three weeks old. As the breeding seasons of the various marine Invertebrates appear to occur in the Irish Sea and the English Channel at about the same times of the year one would expect to find this larva in the plankton in July.

Figs. 61 to 64, Pl. IX, represent four stages in the development of a Spatangoid echinopluteus which has occurred in abundance in the plankton in the latter part of February during the past four years, and again in 1914. It was abundant throughout March, 1914, and numbers of fully developed specimens occurred in the plankton about the middle of April. There are in the Irish Sea only two known species with which this larvae can be correlated, viz., *Echinocardium flavescens* and *Brissopsis lyrifera,* both inhabitants of moderate depths and apparently somewhat locally distributed. On comparing my figures with those of Fuchs (2) of the early stages of the pluteus of *Echinocardium cordatum,* I find so much similarity in the disposition of the skeletal structures of the two forms that I think it probable that the former represent stages in the development of *Echinocardium flavescens.* I have not seen a stage later than that shown in fig. 64, and the absence of any indication of the development of postero-lateral arms shows that even this is an early stage of the echinopluteus. In the case of either of the above-named

species, both inhabitants of moderate depths, it is remarkable that its larva should occur in such large numbers in the comparatively shallow waters of a bay like that of Port Erin, where the tidal current of the open sea is but slightly felt; and that the larva of *Spatangus purpureus*, a much larger species, should not have been similarly distributed in its own season.

The only Spatangoid larva which remains to be mentioned is that of *Echinocyamus pusillus*, for an account of the development of which we are indebted to Théel (15). The echinopluteus of this species (fig. 65, Pl. IX) is stoutly built, and has arms of moderate length. It is easily recognised by the uniform fenestration of the skeletal rods of the post-oral and postero-dorsal pairs of arms, and by the somewhat complicated disposition of the body skeleton. Here again in *Echinocyamus pusillus* we have an inhabitant of moderate depths which, on account of its small size and dull green colour may be overlooked in the contents of the dredge; but which, judging from the number of its dead and denuded tests in a bottom deposit which occurs within a short distance of the Calf of Man, is probably not uncommon in the neighbourhood of Port Erin. Its larva, however, has rarely occurred in the plankton. A small number of fully developed echinoplutei were collected by Gravely and myself by means of a weighted tow-net in July and early August, 1907, and I have since seen an occasional specimen in surface tow-nettings on various dates during the autumnal months, the last being November 1st, 1913.

Larvae of Holothuroidea.

The occurrence of larvae of Holothuroidea in the plankton of Port Erin Bay has been of remarkable rarity

throughout the whole period of my observations. At least six species of Holothuroidea occur in the neighbourhood; and a storm of exceptional violence, which occurred in February, 1902, afforded evidence of the abundance of *Synapta digitata* at a depth within reach of the action of the waves, by casting up a very large number of specimens on the beach. This habitat has not been discovered; nor does it appear to have been again disturbed by wave action during subsequent storms. The larva of this species is the only local one which has been identified. A small number of specimens of the auricularia (text-fig. 1)

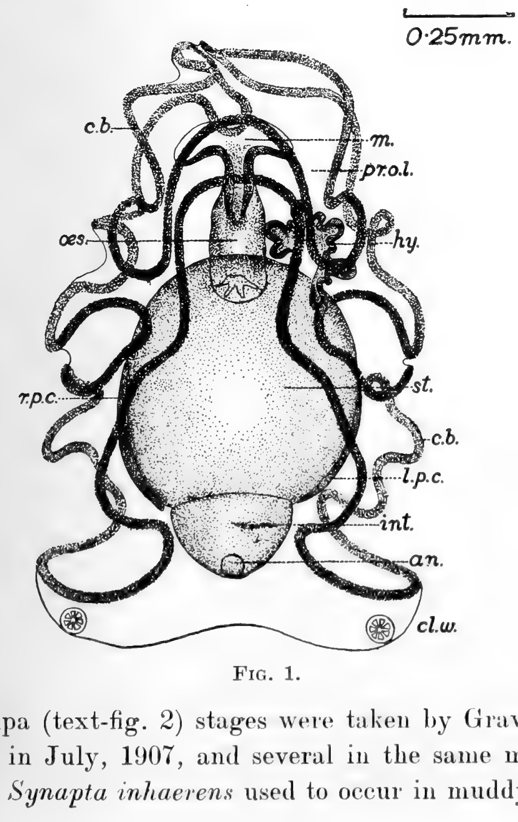


FIG. 1.

and pupa (text-fig. 2) stages were taken by Gravely and myself in July, 1907, and several in the same month of 1908. *Synapta inhaerens* used to occur in muddy gravel

between tide marks in Port Erin Bay, but has not been found by me during the past 16 years.

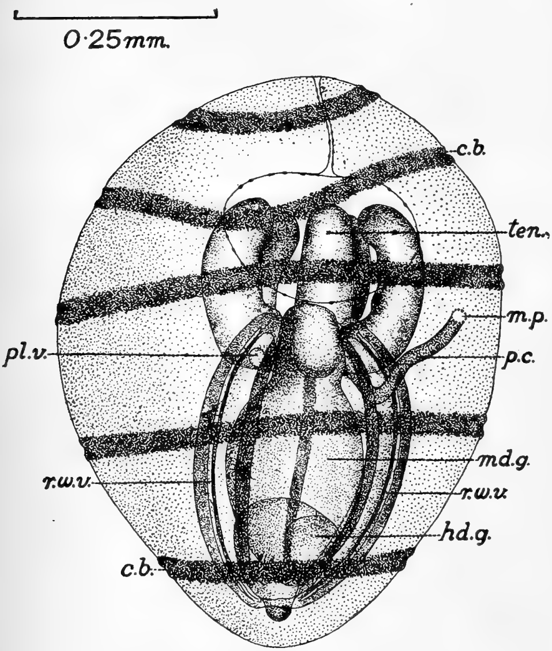


FIG. 2.

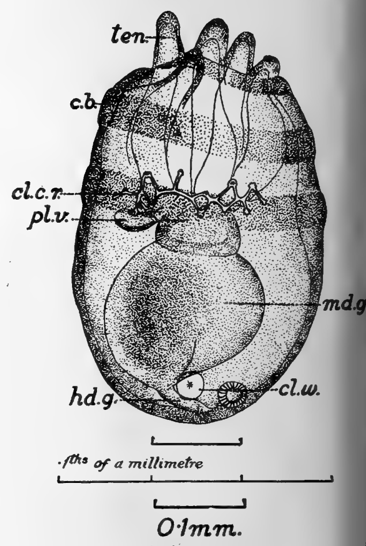


FIG. 3.

Text-fig. 3 represents an interesting stage of the development of a species other than *Synapta,* in which the simple, digitiform tentacles are beginning to protrude from the anterior end of the pupa, and the rudiments of the circumoesophageal calcareous ring are formed. This larva also was taken in July, 1908. There is also in Port Erin Bay a post-larval stage, still unidentified, which has been seen several times in December during the past few years.

List of Works Referred to in the Text.

1. Field, G. W. The Larva of *Asterias vulgaris.* Quart. Journ. Micr. Science, Vol. XXXIV., Pt. 2, 1892.

2. Fuchs, H. M. The Inheritance of the Aboral Process of the Echinocardium Pluteus. Arch. für Entwicklungsmechanik der Organismen, Band XXXV., Heft 3, 1912.

3. Gemmill, J. F. The Development of the Starfish *Solaster endeca,* Forbes. Trans. Zool. Soc. of London, Vol. XX., Pt. i., 1912.

4. Gemmill, J. F. Ann. Report of British Association, Sec. D. Birmingham, 1913.

5. Gemmill, J. F. Ann. Report of British Association, Sec. D. Dundee, 1912.

6. Graham Kerr, J. Loch Sween. Glasgow Naturalist, Vol. IV., No. 2, 1912.

7. Herdman, W. A. Notes on the Fauna of the Isle of Man. Fauna of Liverpool Bay, Vol. I., 1886, pp. 325-327.

8. Herdman, W. A., and Scott, A. An Intensive Study of the Marine Plankton of the South End of the Isle of Man. Reports of the Lancashire Sea-Fisheries Laboratory, No. XVI. (1908), p. 185; No. XVII. (1909), p. 222; No. XVIII. (1910), p. 289; No. XXII. (1913), p. 279. (See p. 382 of this Vol.)

9. Krohn, A. Uber die Larve von *Spatangus purpureus.* Müll. Archiv., 1853.

10. MacBride, E. W. The Development of *Echinus esculentus.* Phil. Trans., Ser. B, Vol. 195, 1903.

11. MacBride, E. W. The Development of *Ophiothrix fragilis.* Quart. Journ. Micr. Science, Vol. 51, Pt. 4, 1907.

12. Mortensen, Th. Echinodermen Larven. Nordisches Plankton. IX., 1901.

13. Mortensen, Th. On the Development of some British Echinoderms. Journ. Mar. Biol. Association, N. Ser., Vol. X., 1913.

14. Scott, A. Report on the Tow-nettings. Report of the Lancashire Sea-Fisheries Laboratory, No. XV., 1907, pp. 78 and 84.

15. Théel, Hj. On the Development of *Echinocyamus pusillus.* Nova Acta Reg. Soc. Sci., Ser. 3, Vol. XV., 1892.

EXPLANATION OF PLATES.

Reference Letters.

a. c. ep. = Ant. cil. epaulette.
ad. = Adambulacral plate.
ad. m. = Adult mouth.
a. l. a. = Antero-lateral arm.
an. = Anus.
a. p. = Apical plate.
arc. = Archenteron.

bl. = Blastopore.
b. t. = Buccal tentacles.

c.b. = Ciliated band.
c.c = Ciliated cells.
cl. c. r. = Circum-oesoph. calcar. ring.
cl. w. = Calcareous wheels.
cn. = Central plate.

dc. = Disc of adult.
d. f. = Disc for fixation.

ech. = Echinus rudiment.
ep. = Epaulettes.

gr. p. = Green pigment.

hd. g. = Hind gut.
hy. = Hydrocoel.

int. = Intestine.

l. a. c. = Left anter. coelom.
l. c. = Left coelom.
l. l. a. = Left larval arm.
l.p.c. = Left poster. coelom.

m. = Mouth.
md. g. = Mid-gut.
mes. = Mesenchyme.
m.f. = Muscular fibres.
m. p. = Madreporic pore.
m. pl. = Madreporic plate.

oes. = Oesophagus.

p. a. = Papillae for temp. fixation.
p. c. = Pore canal.
p. c. ep. = Poster. ciliated epaulette.
pd. = Pedicellaria.
pl. v. = Polian vesicle.
pr. o. a. = Pre-oral arm.
pr. o. l. = Pre-oral lobe.
pto. d. a. = Postero-dorsal arm.
pt. o. a. = Post-oral arm.
pto. l. a. = Postero-lateral arm.

r. a. c. = Right anter. coelom.
r. c. = Right coelom.
rl. = Radial plate.
r. l. a. = Right larval arm.
r. p. c. = Right poster. coelom.
r. w. v. = Radial water vessel.

sk. p. = Skeletal plates.
sk. r. = Skeletal rods.
sk. rs. = Skeletal rosette.
sp. = Spine.
sph. = Sphaeridium.
st. = Stomach.
std. = Stomodoeal invagination

ten. = Tentacles.
t. f. = Tube-feet.
tl. = Terminal plate.

u. ab. p. = Unpaired aboral process.
u. t. = Unpaired tube-foot or tentacle.

yl. p. = Yellow pigment.

Plate I.

Figs. 1 to 9. Stages of development of *Asterias rubens.*

Fig. 1. Optical section of blastula.

Fig. 2. Optical section of early gastrula.

Fig. 3. Optical section of later gastrula.

Fig. 4. Ventral view of an early bipinnaria.

Fig. 5. Slightly diagrammatic optical section of bipinnaria of about the same age.

Fig. 6. Ventral view of an older bipinnaria.

Fig. 7. View from the left side of a bipinnaria of about the same age.

Fig. 8. Ventral view of a fully-formed bipinnaria.

Fig. 9. Dorsal view of a still older bipinnaria.

Fig. 10. Ventral view of bipinnaria of *Asterias glacialis.* (Compare with fig. 9).

Plate II.

Fig. 11. Bipinnaria of *Luidia ciliaris*, viewed from the left side.

Fig. 12. Ventral view of a slightly older bipinnaria of same.

Fig. 13. Brachiolaria of an Asterid not yet identified, undergoing metamorphosis. Viewed from the left side.

Figs. 14 to 18. Stages of the development of *Solaster endeca* (?).

Fig. 15. Young larva, viewed from the right side.

Fig. 16. Older larva, viewed from the left side.

Fig. 17. Still older larva, in which the larval arms are fully developed.

Fig. 18. Oral view of a larva towards the end of the free-swimming stage.

Fig. 19. Larva of (?) *Solaster sp.*, viewed from the right side.

Plate III.

Fig. 20. Ventral view of a full-grown ophiopluteus mancus.

Fig. 21. Young specimen of the same. The coelomic vesicles in optical section.

Fig. 22. Ventral view of slightly older ophiopluteus.

Fig. 23. Ventral view of a still older ophiopluteus.

Fig. 24. Ventral view of a still older ophiopluteus in an early stage of metamorphosis.

Fig. 25. Ventral view of an ophiopluteus in which metamorphosis is just beginning.

Plate IV.

Fig. 26. Ventral view of a metamorphosing ophiopluteus mancus. Only three lobes of the hydrocoel can be discerned in this specimen.

Fig. 27. Ventral view of a slightly older specimen, with the hydrocoel as in fig. 26. For *ad.* in this figure read *m.pl.*

Fig. 28. Ventral view of a metamorphosing ophiopluteus mancus.

Fig. 29. Dorsal view of an ophiopluteus mancus in which metamorphosis is well advanced.

Fig. 30. Dorsal view of an ophiopluteus mancus in which metamorphosis is nearly complete.

Fig. 31. Dorsal view of a post-larva, freed from the pluteus, but still pelagic.

Plate V.

Fig. 32. Ventral view of a full-grown ophiopluteus of *Ophiothrix fragilis.*

Fig. 32a. Posterior portion of the skeleton of the same.

Fig. 33. Ventral view of a young ophiopluteus of *Ophiothrix fragilis.*

Fig. 34. Ventral view of a slightly older ophiopluteus of *Ophiothrix fragilis.*

Fig. 35. Dorsal view of an ophiopluteus of *Ophiothrix fragilis.* (Compare with fig. 29).

Fig. 36. Post-larval but still pelagic *Ophiothrix fragilis.* From an unstained preparation.

Plate VI.

Fig. 37. Ventral view of the ophiopluteus doubtfully correlated by Mortensen with *Ophiopholis aculeata*.

Fig. 37A. Posterior portion of the skeleton of the same.

Fig. 38. Ventral view of an "epauletted" ophiopluteus.

Fig. 38A. Posterior portion of the skeleton of the same.

Fig. 39. Ventral view of a pluteus paradoxus, Müll., correlated by Mortensen with *Ophioglypha albida* (Forbes).

Fig. 39A. Posterior portion of the skeleton of the same.

Fig. 40. Dorsal view of a metamorphosing pluteus paradoxus.

Fig. 41. Oral view of a post-larval *Ophiura albida*, Forbes.

Fig. 42. Post-larva of the same. From an unstained preparation.

Plate VII.

Fig. 43. Ventral view of the ophiopluteus correlated by Mortensen with *Ophiura ciliaris* (Linn.).

Fig. 43A. Posterior portion of the skeleton of the same.

Fig. 44. Dorsal view of an ophiopluteus compressus.

Fig. 44A. Posterior portion of the skeleton of the same.

Fig. 45. The same specimen more highly magnified.

Fig. 46. An unidentified ophiopluteus, in which metamorphosis is nearly complete.

Fig. 46A. Posterior portion of the skeleton of the same.

Fig. 47. Pelagic post-larva of the same.

Fig. 48. Pelagic post-larva not yet identified.

Plate VIII.

Fig. 49. Echinopluteus of *Echinus esculentus*, four weeks old. After MacBride.

Fig. 50. Echinopluteus of *Echinus esculentus*, three weeks old. After MacBride.

Fig. 51. Echinopluteus of *Echinus miliaris* three weeks old. After MacBride.

Fig. 52. Body of echinopluteus of *Echinus miliaris*, viewed from the left side.

Fig. 53. Ventral view of an echinopluteus of *Echinus miliaris*.

Fig. 54. An older echinopluteus of the same, viewed from the left side.

Fig. 55. Ventral view of a still older echinopluteus of the same.

Fig. 56. Metamorphosing echinopluteus of *Echinus miliaris*, viewed from the left side.

Plate IX.

Fig. 57. Aboral view of a post-larva of *Echinus miliaris*.

Fig. 58. Ventral view of a full-grown echinopluteus of *Echinocardium cordatum*.

Fig. 59. Side view of a post-larva of the same.

Fig. 60. Oro-lateral view of a post-larva of the same. The spines are omitted.

Figs. 61 to 64. Four stages of an unidentified Spatangoid echinopluteus.

Fig. 65. Dorsal view of the echinopluteus of *Echinocyamus pusillus*.

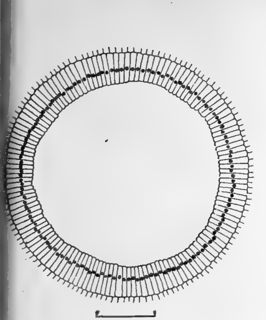


Fig.1

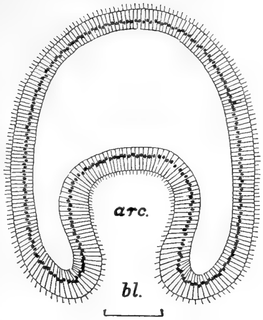


Fig.2

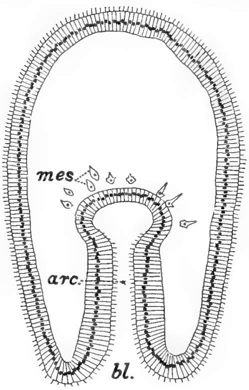


Fig.3

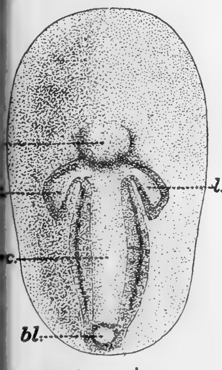


Fig.4

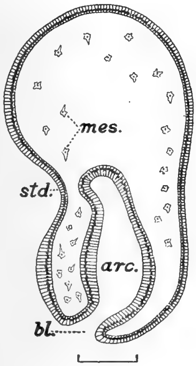


Fig. 5

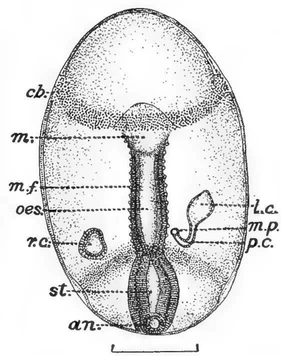


Fig.6

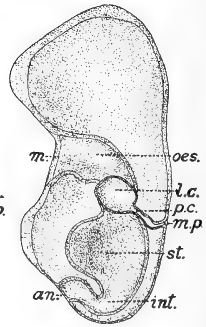


Fig.7

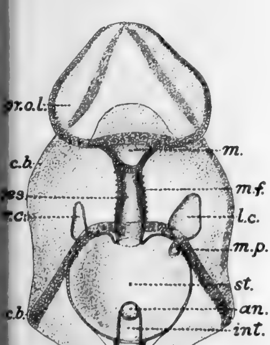


Fig.8

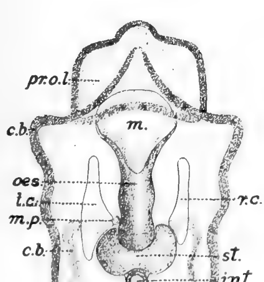


Fig.9

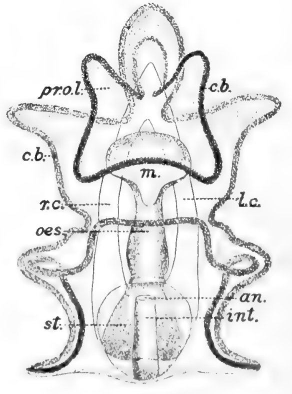


Fig.10

C. C. del.

ECHINODERM LARVÆ

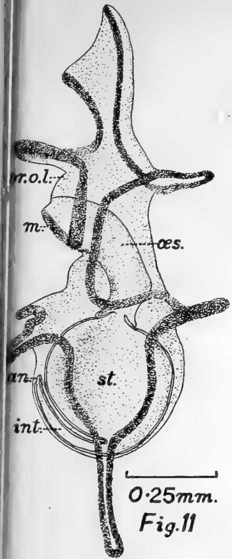


Fig.11

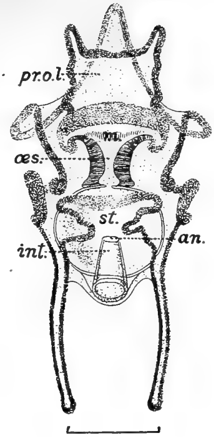


Fig.12

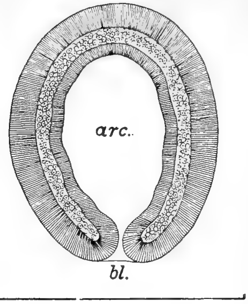


Fig.14

Fig.13

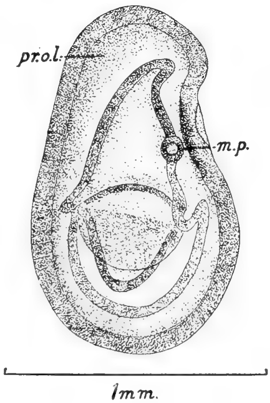


Fig.15

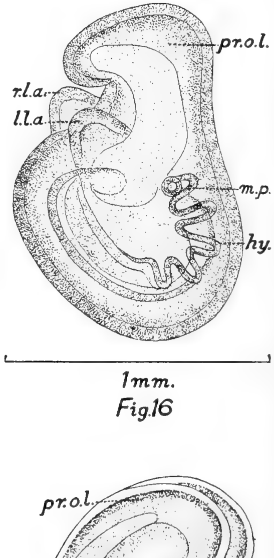


Fig.16

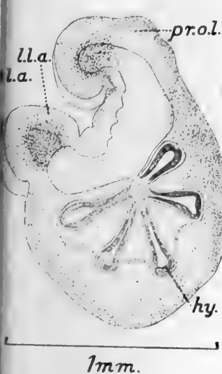


Fig.17

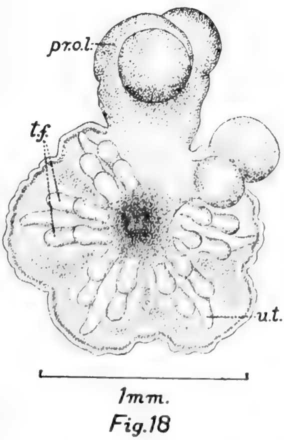


Fig.18

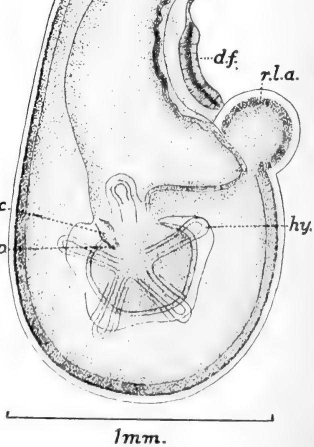
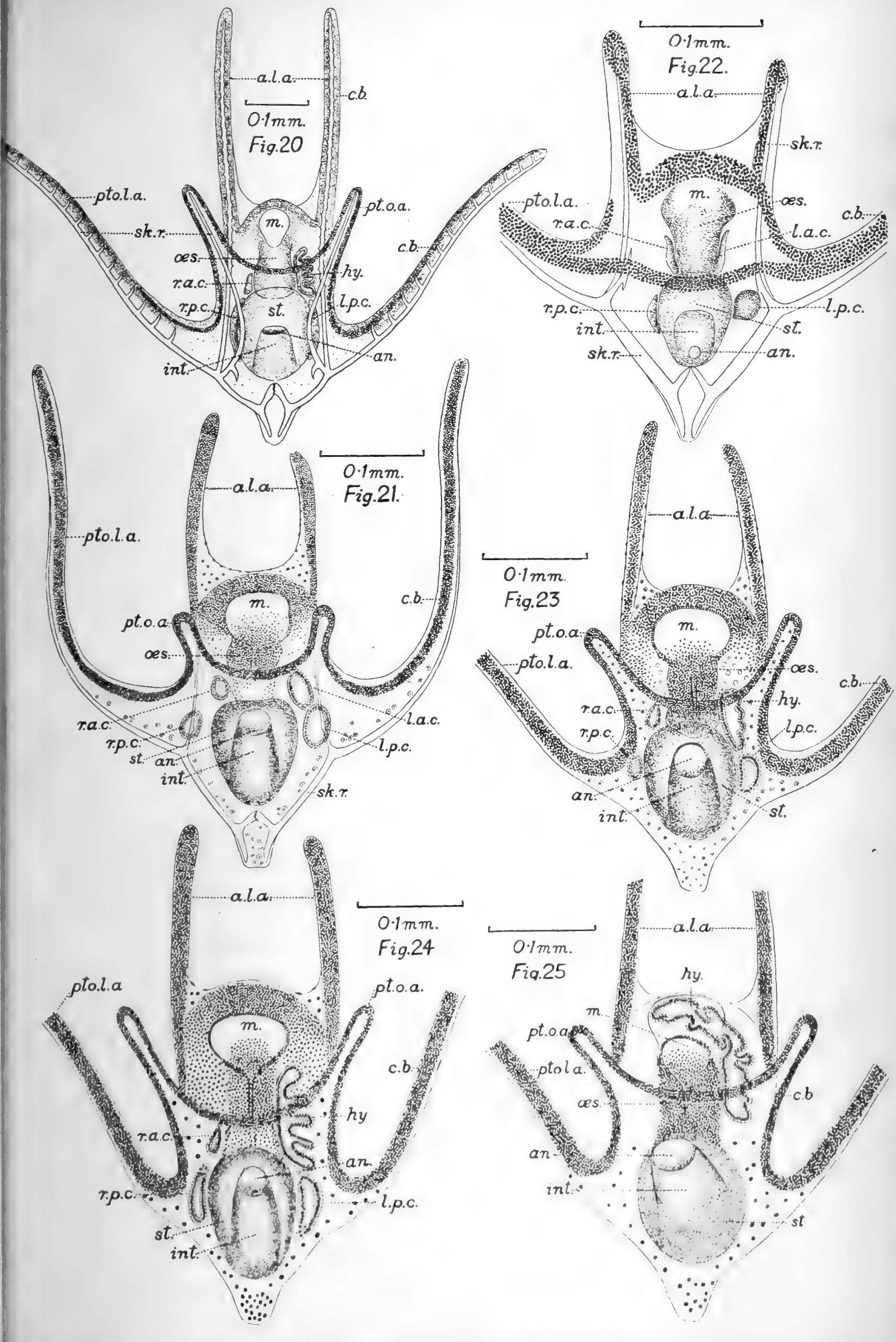


Fig.19

ECHINODERM LARVÆ



H. C. C. del.

ECHINODERM LARVÆ

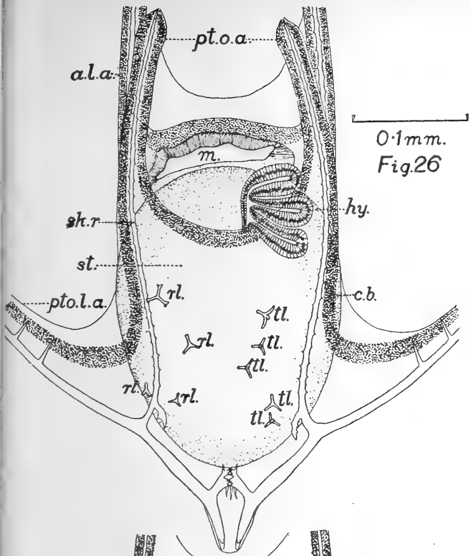


Fig.26

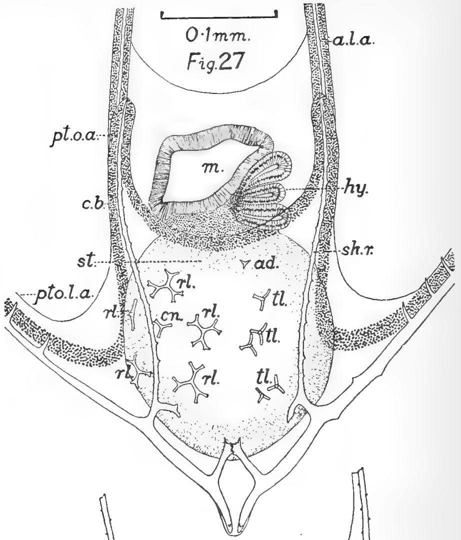


Fig.27

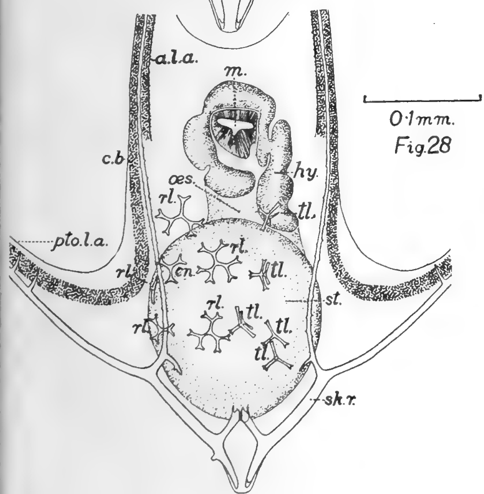


Fig.28

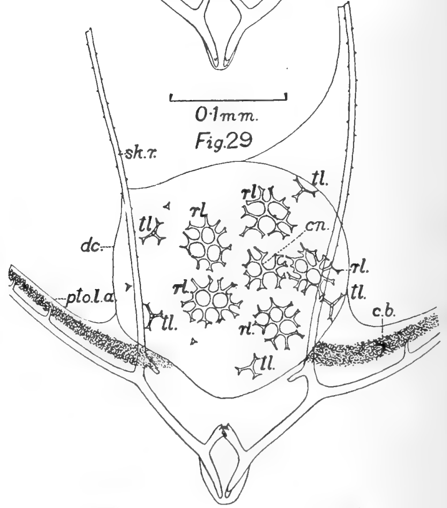


Fig.29

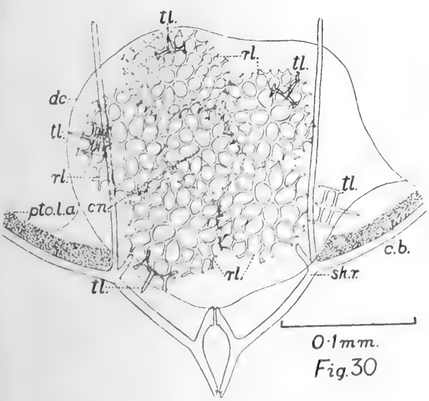


Fig.30

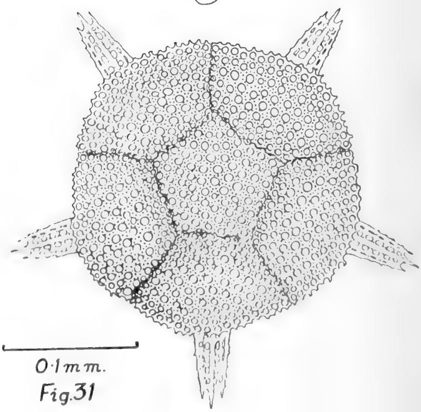
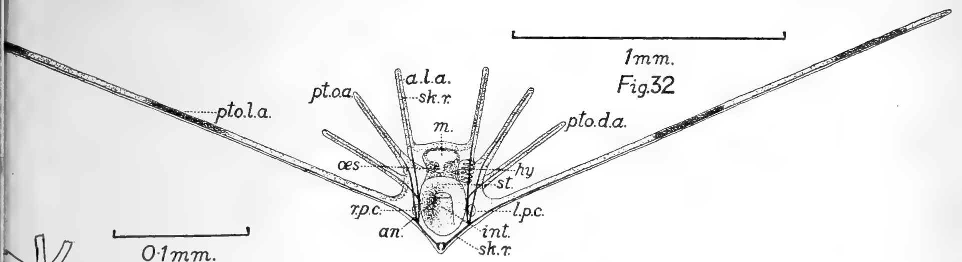
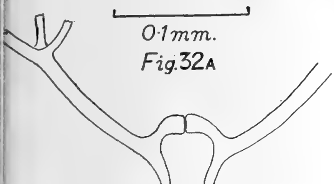


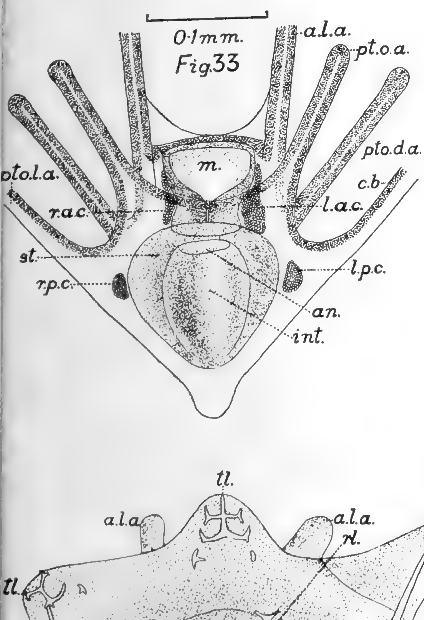
Fig.31

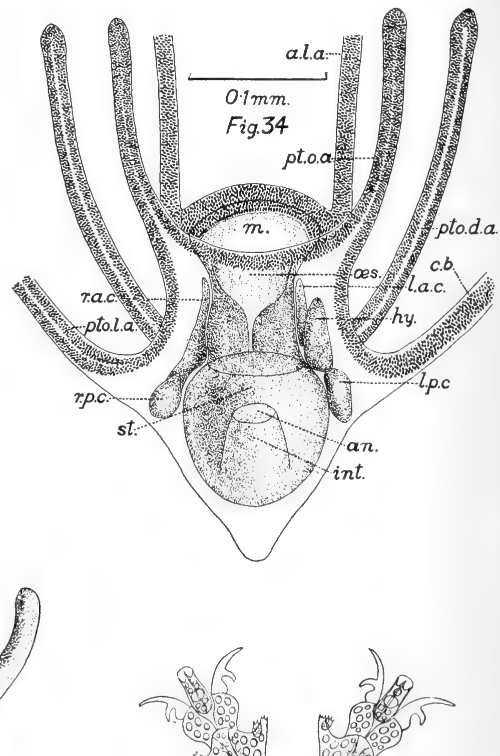
H. C. C. del.

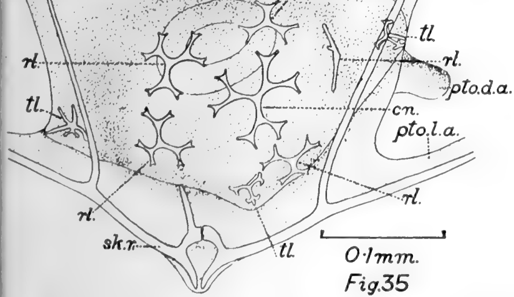
ECHINODERM LARVÆ

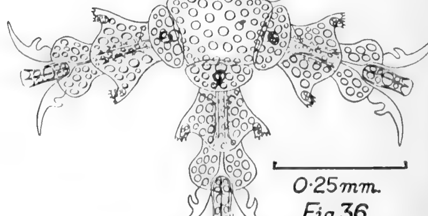






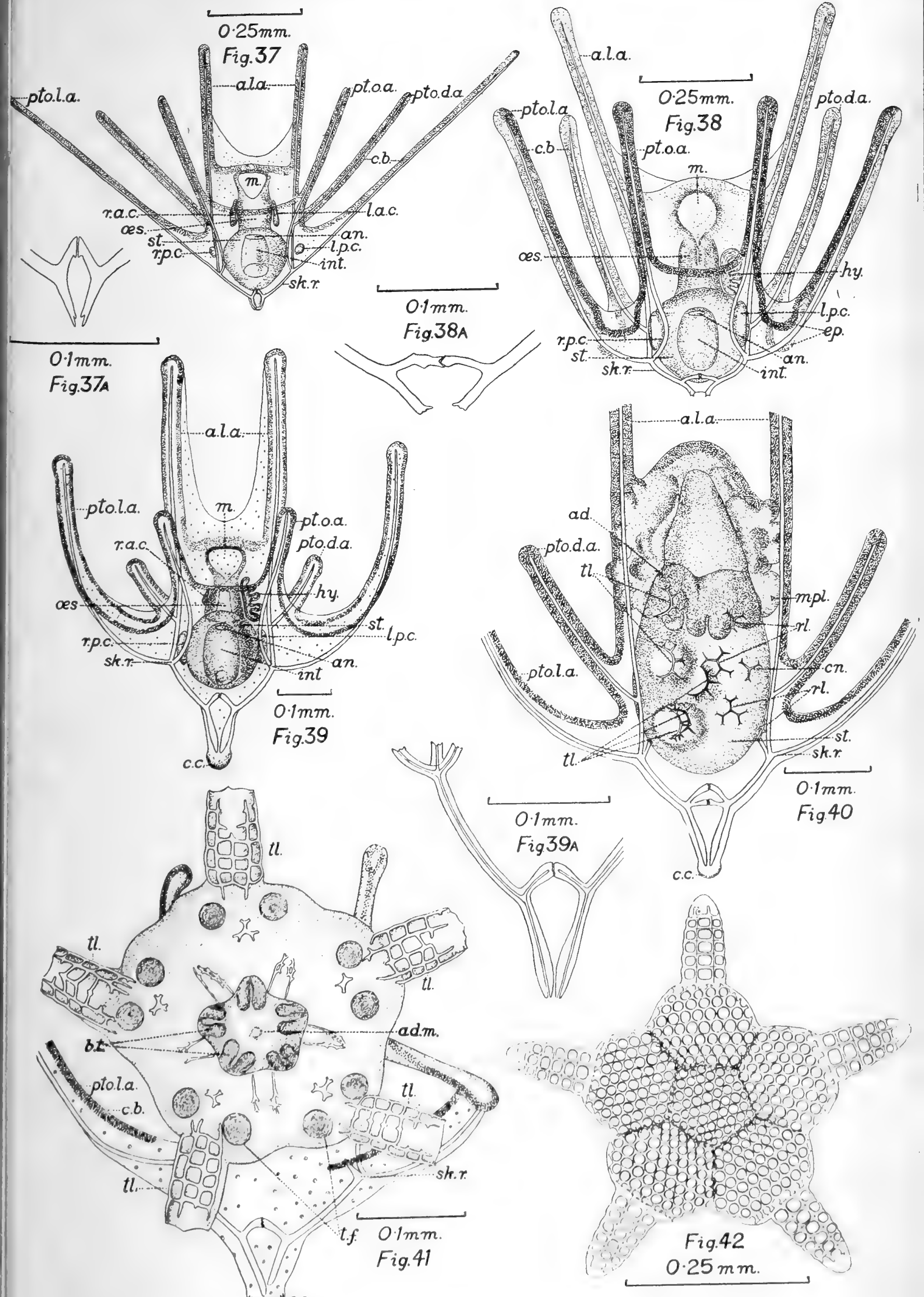






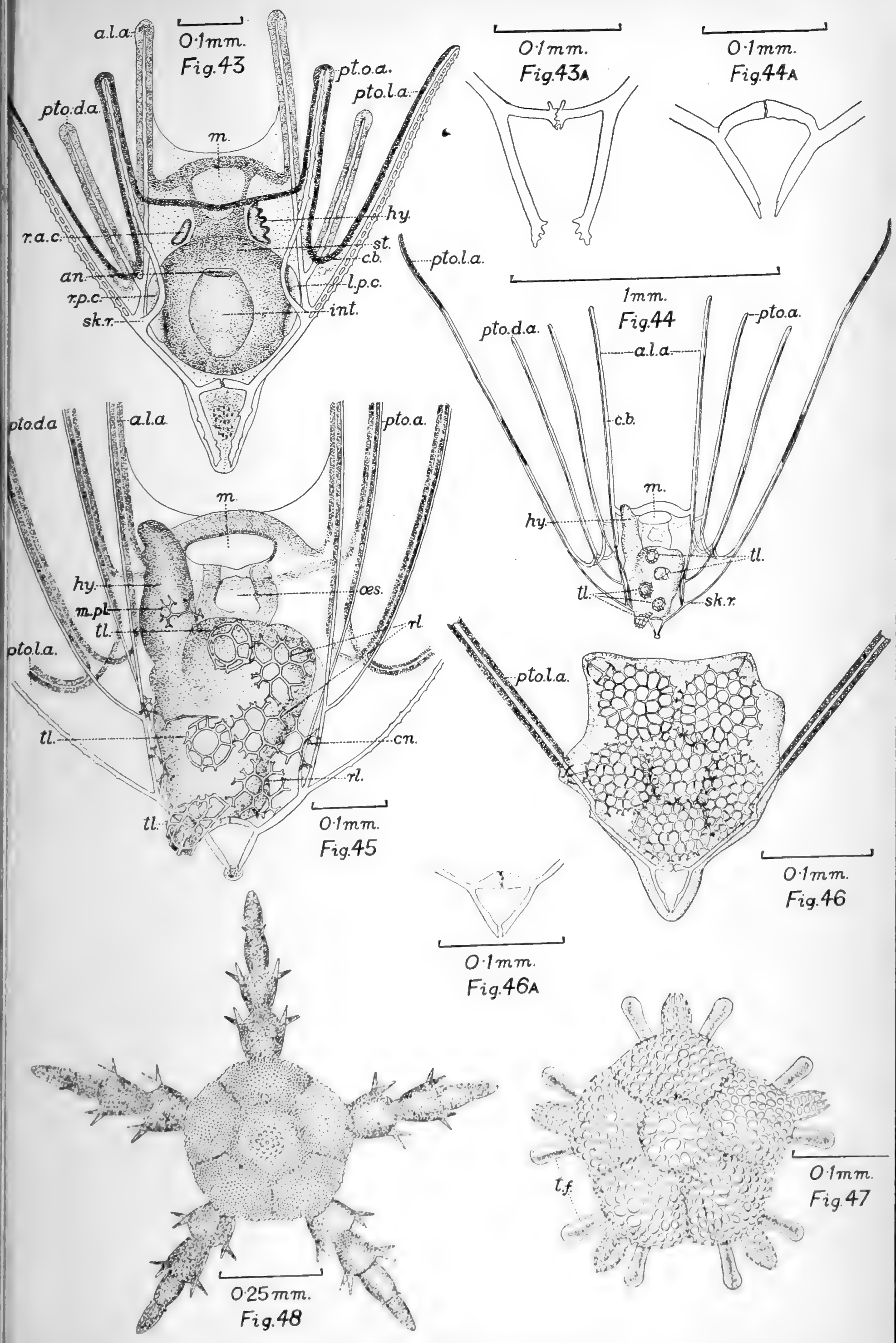
H. C. C. *del.*

ECHINODERM LARVÆ



H. C. C. del.

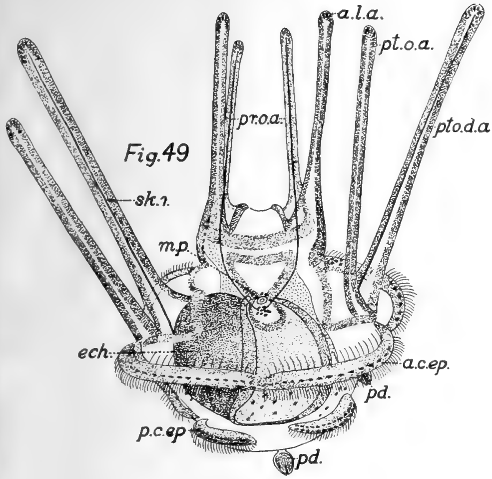
ECHINODERM LARVÆ



H. C. C. del.

ECHINODERM LARVÆ

Fig. 49



0·25 mm.

Fig. 52

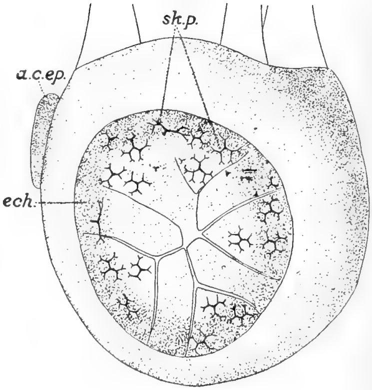


Fig. 51

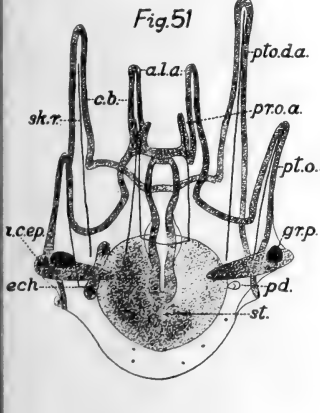
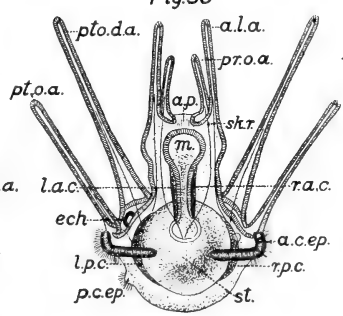
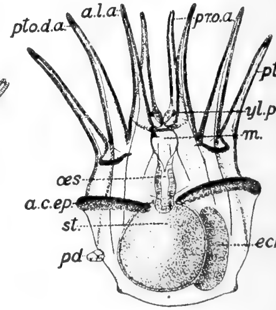


Fig. 50



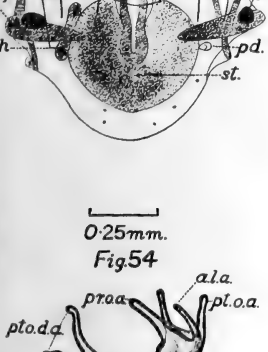
0·25 mm

Fig. 53



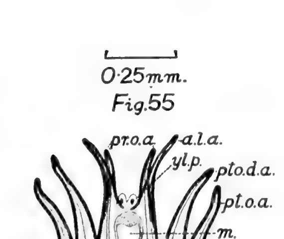
0·25 mm.

Fig. 54



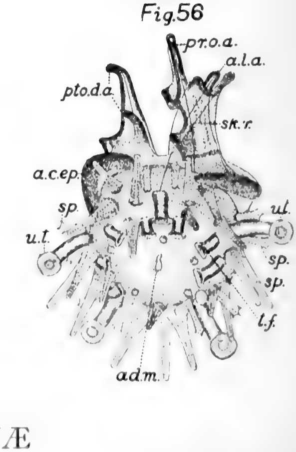
0·25 mm.

Fig. 55



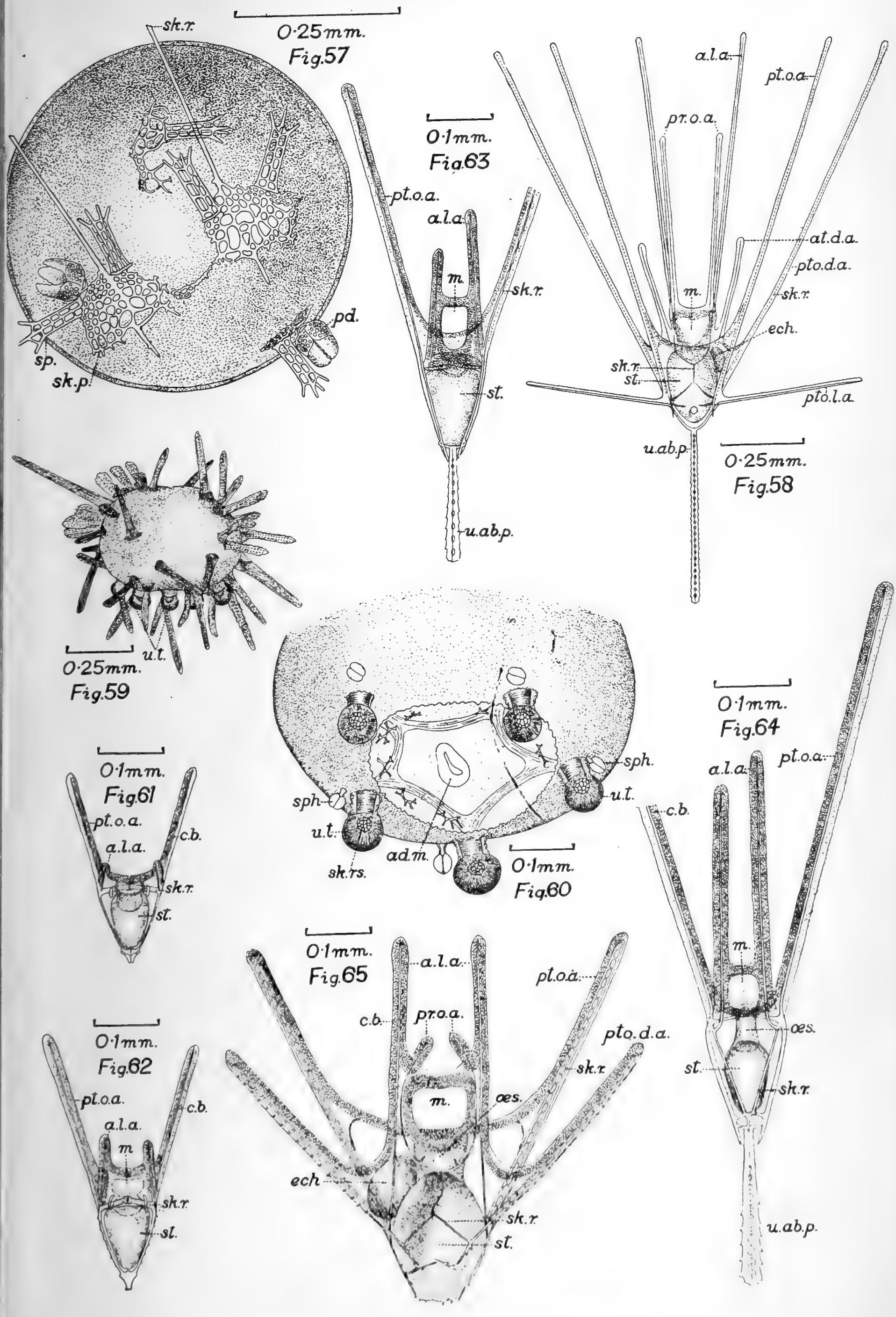
0·25 mm.

Fig. 56



H. C. C. del.

ECHINODERM LARVÆ



H. C. C. del.

ECHINODERM LARVÆ